

PALEONTOGRAPHICAL SOCIETY.

VOL. XL.

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STIGMARIA FICOIDES

(MORPHOLOGY AND HISTOLOGY).

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Presented by ~~Paleontographical Society~~.

December \_\_\_\_\_, 1906.

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## VOLUME XL.

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AND IN PREPARATION, WITH THE NAMES OF THEIR RESPECTIVE AUTHORS;
- III. THE DATES OF ISSUE OF THE ANNUAL VOLUMES;
- IV. A GENERAL SUMMARY, SHOWING THE NUMBER OF THE PAGES, PLATES, FIGURES,  
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## § I. CATALOGUE OF WORKS

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### THE PALÆONTOGRAPHICAL SOCIETY:

*Showing the ORDER of publication; the YEARS during which the Society has been in operation; and the CONTENTS of each yearly Volume.*

Vol. I.	Issued for the Year 1847	The Crag Mollusca, Part I, Univalves, by Mr. S. V. Wood, 21 plates.
„ II.	„	1848 { The Reptilia of the London Clay, Vol. I, Part I, Chelonia, &c., by Profs. Owen and Bell, 38 plates. The Eocene Mollusca, Part I, Cephalopoda, by Mr. F. E. Edwards, 9 plates.
„ III.*	„	1849 { The Entomostraca of the Cretaceous Formations, by Mr. T. R. Jones, 7 plates. The Permian Fossils, by Prof. Wm. King, 29 plates. The Reptilia of the London Clay, Vol. I, Part II, Crocodilia and Ophidia, &c., by Prof. Owen, 18 plates. The Fossil Corals, Part I, Crag, London Clay, Cretaceous, by Messrs. Milne Edwards and Jules Haime, 11 plates.
„ IV. /	„	1850 { The Crag Mollusca, Part II, No. 1, by Mr. S. V. Wood, 12 plates. The Mollusca of the Great Oolite, Part I, Univalves, by Messrs. Morris and Lycett, 15 plates. The Fossil Brachiopoda, Vol. I, Part III, No. 1, Oolitic and Liassic, by Mr. Davidson, 13 plates.
„ V.	„	1851 { The Reptilia of the Cretaceous Formations, by Prof. Owen, 39 plates. The Fossil Corals, Part II, Oolitic, by Messrs. Milne Edwards and Jules Haime, 19 plates. The Fossil Lepadidæ, by Mr. Charles Darwin, 5 plates.
„ VI.	„	1852 { The Fossil Corals, Part III, Permian and Mountain-limestone, by Messrs. Milne Edwards and Jules Haime, 16 plates. The Fossil Brachiopoda, Vol. I, Part I, Tertiary, by Mr. Davidson, 2 plates. The Fossil Brachiopoda, Vol. I, Part II, No. 1, Cretaceous, by Mr. Davidson, 5 plates. The Fossil Brachiopoda, Vol. I, Part III, No. 2, Oolitic, by Mr. Davidson, 5 plates. The Eocene Mollusca, Part II, Pulmonata, by Mr. F. E. Edwards, 6 plates. The Radiaria of the Crag, London Clay, &c., by Prof. E. Forbes, 4 plates.
„ VII.	„	1853 { The Fossil Corals, Part IV, Devonian, by Messrs. Milne Edwards and Jules Haime, 10 plates. The Fossil Brachiopoda, Introduction to Vol. I, by Mr. Davidson, 9 plates. The Mollusca of the Chalk, Part I, Cephalopoda, by Mr. D. Sharpe, 10 plates. The Mollusca of the Great Oolite, Part II, Bivalves, by Messrs. Morris and Lycett, 8 plates. The Mollusca of the Crag, Part II, No. 2, Bivalves, by Mr. S. V. Wood, 8 plates. The Reptilia of the Wealden Formations, Part I, Chelonia, by Prof. Owen, 9 plates.

\* The Volume for the year 1849 consists of two separate portions, each of which is stitched in a paper cover, on which are printed the dates 1848, 1849, and 1850.



## CATALOGUE OF WORKS—Continued.

Vol. XVII.	Issued for the Year 1863	<ul style="list-style-type: none"> <li>The Trilobites of the Silurian, Devonian, &amp;c., Formations, Part II, by Mr. J. W. Salter, 8 plates.</li> <li>The Fossil Brachiopoda. Vol. III. Part VI, No. 2, Devonian, by Mr. Davidson, 11 plates.</li> <li>The Belemnitide, Part I, Introduction, by Prof. Phillips.</li> <li>The Reptilia of the Liassic Formations, Part I, by Prof. Owen, 16 plates.</li> </ul>
" XVIII.	"	<ul style="list-style-type: none"> <li>1864               <ul style="list-style-type: none"> <li>The Fossil Echinodermata, Oolitic, Vol. II, Part II (Liassic Ophiuroidea), by Dr Wright, 6 plates.</li> <li>The Trilobites of the Silurian, Devonian, &amp;c., Formations, Part III, by Mr. J. W. Salter, 11 plates.</li> <li>The Belemnitide, Part II, Liassic Belemnites, by Prof. Phillips, 7 plates.</li> <li>The Pleistocene Mammalia, Part I, Introduction, Felis spelæa, by Messrs. W. Boyd Dawkins and W. A. Sanford, 5 plates.</li> <li>Title-pages, &amp;c., to the Monographs on the Reptilia of the London Clay, Cretaceous, and Wealden Formations.</li> </ul> </li> </ul>
" XIX.*	"	<ul style="list-style-type: none"> <li>1865               <ul style="list-style-type: none"> <li>The Crag Foraminifera, Part I, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady, 4 plates.</li> <li>Supplement to the Fossil Corals, Part I, Tertiary, by Dr. Duncan, 10 plates.</li> <li>The Fossil Merostomata, Part I, Pterygotus, by Mr. H. Woodward, 9 plates.</li> <li>The Fossil Brachiopoda, Vol. III, Part VII, No. 1, Silurian, by Mr. Davidson, 12 plates.</li> </ul> </li> </ul>
" XX.*	"	<ul style="list-style-type: none"> <li>1866               <ul style="list-style-type: none"> <li>Supplement to the Fossil Corals, Part IV, No. 1, Liassic, by Dr. Duncan, 11 plates.</li> <li>The Trilobites of the Silurian, Devonian, &amp;c., Formations, Part IV (Silurian), by Mr. J. W. Salter, 6 plates.</li> <li>The Fossil Brachiopoda, Vol. III, Part VII, No. 2, Silurian, by Mr. Davidson, 10 plates.</li> <li>The Belemnitide, Part III, Liassic Belemnites, by Prof. Phillips, 13 plates.</li> </ul> </li> </ul>
" XXI.*	"	<ul style="list-style-type: none"> <li>1867               <ul style="list-style-type: none"> <li>Flora of the Carboniferous Strata, Part I, by Mr. E. W. Binney, 6 plates.</li> <li>Supplement to the Fossil Corals, Part IV, No. 2, Liassic, by Dr. Duncan, 6 plates.</li> <li>The Fossil Echinodermata, Cretaceous, Vol. I, Part II, by Dr. Wright, 14 plates.</li> <li>The Fishes of the Old Red Sandstone, Part I, by Messrs. J. Powrie and E. Ray Lankester, 5 plates.</li> <li>The Pleistocene Mammalia, Part II, Felis spelæa, continued, by Messrs. W. Boyd Dawkins and W. A. Sanford, 14 plates.</li> </ul> </li> </ul>
" XXII.*	"	<ul style="list-style-type: none"> <li>1868               <ul style="list-style-type: none"> <li>Supplement to the Fossil Corals, Part II, No. 1, Cretaceous, by Dr. Duncan, 9 plates.</li> <li>The Fossil Merostomata, Part II, Pterygotus, by Mr. H. Woodward, 6 plates.</li> <li>The Fossil Brachiopoda, Vol. III, Part VII, No. 3, Silurian, by Mr. Davidson, 15 plates.</li> <li>The Belemnitide, Part IV, Liassic and Oolitic Belemnites, by Prof. Phillips, 7 plates.</li> <li>The Reptilia of the Kimmeridge Clay, No. 3, by Prof. Owen, 4 plates.</li> <li>The Pleistocene Mammalia, Part III, Felis spelæa, concluded, with F. lynx, by Messrs. W. Boyd Dawkins and W. A. Sanford, 6 plates.</li> </ul> </li> </ul>
" XXIII.*	"	<ul style="list-style-type: none"> <li>1869               <ul style="list-style-type: none"> <li>Supplement to the Fossil Corals, Part II, No. 2, Cretaceous, by Dr. Duncan, 6 plates.</li> <li>The Fossil Echinodermata, Cretaceous, Vol. I, Part III, by Dr. Wright, 10 plates.</li> <li>The Belemnitide, Part V, Oxford Clay, &amp;c., Belemnites, by Prof. Phillips, 9 plates.</li> <li>The Fishes of the Old Red Sandstone, Part I (concluded), by Messrs. J. Powrie and E. Ray Lankester, 9 plates.</li> <li>The Reptilia of the Liassic Formations, Part II, by Prof. Owen, 4 plates.</li> <li>The Crag Cetacea, No. 1, by Prof. Owen, 5 plates.</li> </ul> </li> </ul>
" XXIV.*	"	<ul style="list-style-type: none"> <li>1870               <ul style="list-style-type: none"> <li>The Flora of the Carboniferous Strata, Part II, by Mr. E. W. Binney, 6 plates.</li> <li>The Fossil Echinodermata, Cretaceous, Vol. I, Part IV, by Dr. Wright, 10 plates.</li> <li>The Fossil Brachiopoda, Vol. III, Part VII, No. 4, Silurian, by Mr. Davidson, 13 plates.</li> <li>The Eocene Mollusca, Part IV, No. 3, Bivalves, by Mr. S. V. Wood, 5 plates.</li> <li>The Fossil Mammalia of the Mesozoic Formations, by Prof. Owen, 4 plates.</li> </ul> </li> </ul>

\* These Volumes are issued in two forms of binding; first, with all the Monographs stitched together and enclosed in one cover; secondly, with each of the Monographs separate, and the whole of the separate parts placed in an envelope. The previous Volumes are not in separate parts.



## CATALOGUE OF WORKS—Continued.

Vol. XXXIII*	Issued for the Year 1879			The Eocene Flora, Vol. I, Part I, by Mr. J. S. Gardner and Baron Ettingshausen, 5 plates. Second Supplement to the Crag Mollusca (Univalves and Bivalves), by Mr. S. V. Wood, 6 plates.
				The Fossil Trigonias, No. V ( <i>Conclusion</i> ), by Dr. Lycett, 1 plate.
				The Lias Ammonites, Part II, by Dr. Wright, 10 plates. Supplement to the Reptilia of the Wealden (Goniopholis, Brachydictes, Nannosuchus, Theriosuchus, and Nuthetes), No. IX, by Prof. Owen, 4 plates.
„ XXXIV*	„	1880		The Fossil Elephants (E. primigenius), Part II, by Prof. Leith Adams, 10 plates.
				The Eocene Flora, Vol. I, Part II, by Mr. J. S. Gardner and Baron Ettingshausen, 6 plates.
				The Fossil Echinodermata, Oolitic, Vol. II, Part III (Asteroidea and Ophiuroidea), by Dr. Wright, 3 plates.
„ XXXV*	„	1881		Supplement to the Fossil Brachiopoda, Vol. IV, Part III (Permian and Carboniferous), by Mr. Davidson, 8 plates.
				The Lias Ammonites, Part III, by Dr. Wright, 22 plates.
				The Reptilia of the London Clay, Vol. II, Part I (Chelone) by Prof. Owen, 2 plates.
„ XXXVI*	„	1882		The Fossil Echinodermata, Cretaceous, Vol. I, Part IX, by Dr. Wright, 6 plates.
				Supplement to the Fossil Brachiopoda, Vol. IV, Part IV (Devonian and Silurian, from Budleigh-Salterton Pebble Bed), by Mr. Davidson, 5 plates.
				The Fossil Trigonias (Supplement No. 1), by Dr. Lycett.
„ XXXVII*	„	1883		The Lias Ammonites, Part IV, by Dr. Wright, 10 plates.
				The Reptilia of the Liassic Formations, Part III ( <i>Conclusion</i> ), by Prof. Owen, 13 plates.
				The Fossil Elephants (E. primigenius and E. meridionalis), Part III ( <i>Conclusion</i> ), by Prof. Leith Adams, 13 plates.
„ XXXVIII*	„	1884		The Eocene Flora, Vol. I, Part III ( <i>Conclusion</i> ), by Mr. J. S. Gardner and Baron Ettingshausen, 2 plates.
				Third Supplement to the Crag Mollusca, by the late Mr. S. V. Wood, 1 plate.
				The Fossil Echinodermata, Cretaceous, Vol. I, Part X ( <i>Conclusion</i> ), by Dr. Wright, 5 plates.
„ XXXIX*	„	1885		Supplement to the Fossil Brachiopoda, Vol. IV, Part V ( <i>Conclusion</i> ), by Dr. Davidson.
				Supplement to the Fossil Brachiopoda, Vol. V, Part I (Devonian and Silurian), by Dr. Davidson, 7 plates.
				The Lias Ammonites, Part V, by Dr. Wright, 22 plates.
„ XL*	„	1886		The Eocene Flora, Vol. II, Part I, by Mr. J. S. Gardner, 9 plates.
				The Trilobites of the Silurian, Devonian, &c., Formations, Part V ( <i>Conclusion</i> ), by the late Mr. J. W. Salter.
				The Carboniferous Trilobites, Part I, by Dr. H. Woodward, 6 plates.
„ XLI*	„	1887		Supplement to the Fossil Brachiopoda, Vol. V, Part II (Silurian), by Dr. Davidson, 10 plates.
				The Fossil Trigonias (Supplement No. 2), by the late Dr. Lycett, 4 plates.
				The Lias Ammonites, Part VI, by Dr. Wright, 8 plates.
„ XLII*	„	1888		The Eocene Flora, Vol. II, Part II, by Mr. J. S. Gardner, 11 plates.
				The Carboniferous Entomostraca, Part I, No. 2 ( <i>Conclusion</i> ), by Prof. T. Rupert Jones, Mr. J. W. Kirkby, and Prof. G. S. Brady, 2 plates.
				The Carboniferous Trilobites, Part II, by Dr. H. Woodward, 4 plates.
„ XLIII*	„	1889		Supplement to the Fossil Brachiopoda, Vol. V, Part III ( <i>Conclusion</i> ), by Dr. Davidson, 4 plates.
				The Lias Ammonites, Part VII, by Dr. Wright, 10 plates.
				The Eocene Flora, Vol. II, Part III ( <i>Conclusion</i> ), by Mr. J. S. Gardner, 7 plates.
„ XLIV*	„	1890		The Stromatoporeids, Part I, by Prof. Alleyne Nicholson, 11 plates.
				The Fossil Brachiopoda (Bibliography), Vol. VI ( <i>Conclusion</i> ), by the late Dr. Davidson and Mr. W. H. Dalton.
				The Lias Ammonites, Part VIII ( <i>Conclusion</i> ), by the late Dr. Wright, 1 plate.
„ XLV*	„	1891		The Morphology and Histology of Stigmaria Ficoides, by Prof. W. C. Williamson, 15 plates.
				The Fossil Sponges, Part I, by Dr. C. J. Hinde, 8 plates.
				The Jurassic Gasteropoda, Part I, by Mr. W. H. Hudleston.
„ XLVI*	„	1892		The Inferior Oolite Ammonites, Part I, by Mr. S. S. Buckman, 6 plates.
				The Pleistocene Mammalia, Part VI, by Prof. Boyd Dawkins, 7 plates.

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## § II. LIST OF MONOGRAPHS

### Completed, in course of Publication, and in Preparation.

#### 1. MONOGRAPHS which have been COMPLETED, and which may be bound as separate Volumes:—

- The Morphology and Histology of *Stigmaria ficoides* by Prof. W. C. Williamson. (*Complete with Title-page and Index in the Volume for 1886.*)
- The Eocene Flora, Vol. I (Filices), by Mr. J. S. Gardner and Baron Ettingshausen. (*Complete in the Volumes for the years 1879, 1880, and 1882. Title-page, Index, and directions for the binding, will be found in the Volume for 1882.*)
- The Eocene Flora, Vol. II (Gymnospermæ), by Mr. J. S. Gardner. (*Complete in the Volumes for 1883, 1884, and 1885. Title-page, Index, and directions for the binding, will be found in the Volume for 1885.*)
- The Carboniferous and Permian Foraminifera (the genus *Fusulina* excepted), by Mr. H. B. Brady. (*Complete in the Volume for the year 1876.*)
- The Tertiary, Cretaceous, Oolitic, Devonian, and Silurian Corals, by MM. Milne-Edwards and J. Haime. (*Complete in the Volumes for the years 1849, 1851, 1852, 1853, and 1854. The Title-page and Index, with corrected explanations of Plates XVII and XVIII, will be found in the Volume for the year 1854.*)
- The Polyzoa of the Crag, by Mr. G. Busk. (*Complete with Title-page and Index in the Volume for the year 1857.*)
- The Tertiary Echinodermata, by Professor Forbes. (*Complete with Title-page in the Volume for the year 1852.*)
- The Fossil Cirripedes, by Mr. C. Darwin. (*Complete in the Volumes for the years 1851, 1854, and 1858. The Title-page will be found in the Volume for the year 1854, and the Index in the Volume for the year 1858.*)
- The Post-Tertiary Entomostraca, by Mr. G. S. Brady, the Rev. H. W. Crosskey, and Mr. D. Robertson. (*Complete, with Title-page and Index, in the Volume for the year 1874.*)
- The Tertiary Entomostraca, by Prof. T. Rupert Jones. (*Complete, with Title-page and Index, in the Volume for the year 1855.*)
- The Cretaceous Entomostraca, by Prof. T. Rupert Jones. (*Complete, with Title-page and Index, in the Volume for the year 1849.*)
- The Carboniferous Entomostraca, Part I (Cypridinadæ and their allies), by Prof. T. Rupert Jones, Mr. J. W. Kirkby, and Prof. G. S. Brady. (*Complete in the volumes for 1874 and 1884. The Title-page and Index will be found in the Volume for the year 1884.*)
- The Fossil Estheriæ, by Prof. T. Rupert Jones. (*Complete, with Title-page and Index, in the Volume for the year 1860.*)
- The Trilobites of the Cambrian, Silurian, and Devonian Formations, by Mr. J. W. Salter. (*Complete in the Volumes for the years 1862, 1863, 1864, 1866, and 1883. The Title-page and Index, with directions for the binding, will be found in the Volume for the year 1883.*)



- The Fossil Merostomata, by Dr. H. Woodward. (*Complete in the Volumes for the years 1865, 1868, 1871, 1872, and 1878. The Title-page and Index, with directions for the binding, will be found in the Volume for the year 1878.*)
- The Fossil Brachiopoda (Tertiary, Cretaceous, Oolitic, and Liassic), Vol. I, by Mr. T. Davidson. (*Complete in the Volumes for the years 1850, 1852, 1853, and 1854. The Index will be found in the Volume for the year 1854, and corrected Title-page in that for 1870.*)
- The Fossil Brachiopoda (Permian and Carboniferous), Vol. II, by Mr. T. Davidson. (*Complete in the Volumes for the years 1856, 1857, 1858, 1859, and 1860. The Index will be found in the Volume for the year 1860, and corrected Title-page in that for 1870.*)
- The Fossil Brachiopoda (Devonian and Silurian), Vol. III, by Mr. T. Davidson. (*Complete in the Volumes for the years 1862, 1863, 1865, 1866, 1868, and 1870. The Title-page and Index will be found in the Volume for the year 1870.*)
- The Fossil Brachiopoda, Vol. IV, by Dr. T. Davidson. Supplements: Tertiary, Cretaceous, Jurassic, Triassic, Permian, and Carboniferous. (*Complete in the Volumes for the years 1873, 1876, 1878, 1880, 1881, and 1882. The Title-page and Index, with directions for the binding will be found in the Volume for the year 1882.*)
- The Fossil Brachiopoda, Vol. V, by Dr. T. Davidson. Supplements: Devonian and Silurian. Appendix to Supplements, General Summary, Catalogue and Index of the British Species. (*Complete in the Volumes for the years 1882, 1883, and 1884. The Title-page, with directions for the binding will be found in the Volume for 1884.*)
- The Fossil Brachiopoda, Vol. VI, by Dr. T. Davidson and Mr. W. H. Dalton. Bibliography. (*Complete in the Volume for the year 1885.*)
- The Eocene Bivalves, Vol. I, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volumes for the years 1859, 1862, and 1870. The directions for the binding will be found in the Volume for the year 1870.*)
- Supplement to the Eocene Bivalves, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volume for the year 1877.*)
- The Eocene Cephalopoda and Univalves, Vol. I, by Mr. F. E. Edwards and Mr. S. V. Wood. (*Complete in the Volumes for the years 1848, 1852, 1854, 1855, 1858, and 1877. The Title-page, Index, and directions for the binding, will be found in the Volume for the year 1877.*)
- The Mollusca of the Crag, Vol. I, Univalves, by Mr. S. V. Wood. (*The Text, Plates, and Index, will be found in the Volume for the year 1847, and the Title-page will be found in the Volume for the year 1855.*)
- The Mollusca of the Crag, Vol. II, Bivalves, by Mr. S. V. Wood. (*Complete in the Volumes for the years 1850, 1853, 1855, 1858, and 1873. The Title-page will be found in the Volume for the year 1873, and the Index will be found in the Volume for the year 1855, and a Note in the Volume for the year 1858.*)
- The Mollusca of the Crag, Vol. III, Supplement, by Mr. S. V. Wood. (*Complete in the Volumes for the years 1871 and 1873. The Title-page and Index will be found in the Volume for the year 1873.*)
- Second Supplement to the Crag Mollusca, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volume for the year 1879.*)
- Third Supplement to the Crag Mollusca, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volume for the year 1882.*)

- The Great Oolite Mollusca, by Professor Morris and Dr. Lycett. (*Complete in the Volumes for the years 1850, 1853, and 1854. The Title-page and Index will be found in the Volume for the year 1854.*)
- The Fossil Trigonæ, by Dr. Lycett. (*Complete in the Volumes for the years 1872, 1874, 1875, 1877, and 1879. The directions for the binding will be found in the Volume for the year 1879.*)
- Supplement to the Fossil Trigonæ, by Dr. Lycett. (*Complete in the Volumes for the years 1881 and 1883. The Title-page, Index, with directions for the binding, will be found in the Volume for the year 1883.*)
- The Oolitic Echinodermata, Vol. I, Echinoidea, by Dr. Wright. (*Complete in the Volumes for the years 1855, 1856, 1857, 1858, and 1878. Title-page, Index, and directions for the binding, will be found in the Volume for the year 1878.*)
- The Oolitic Echinodermata, Vol. II, Asteroidea, by Dr. Wright. (*Complete in the Volumes for the years 1861, 1864, and 1880. Title-page, Index, and directions for the binding, will be found in the Volume for the year 1880.*)
- The Cretaceous Echinodermata, Vol. I, Echinoidea, by Dr. Wright. (*Complete in the Volumes for the years 1862, 1867, 1869, 1870, 1872, 1873, 1875, 1878, 1881, and 1882. The Title-page and Index, with directions for the binding, will be found in the Volume for the year 1882.*)
- The Cretaceous (Upper) Cephalopoda, by Mr. D. Sharpe. (*Complete in the Volumes for the years 1853, 1854, and 1855, but wants Title-page and Index.*)
- The Lias Ammonites, by Dr. Wright. (*Complete in the Volumes for the years 1878, 1879, 1880, 1881, 1882, 1883, 1884, and 1885. The Title-page and Index, with directions for the binding, will be found in the Volume for the year 1885.*)
- The Fossils of the Permian Formation, by Professor King. *Complete, with Title-page and Index, in the Volume for the year 1849. Corrected explanations of Plates XXVIII and XXVIII\* will be found in the Volume for the year 1854.*)
- The Reptilia of the London Clay (and of the Bracklesham and other Tertiary Beds), Vol. I, by Professors Owen and Bell. (*Complete in the Volumes for the years 1848, 1849, 1856, and 1864. Directions for the binding, Title-page, and Index, will be found in the Volume for the year 1864.*)
- The Reptilia of the Cretaceous Formations, by Prof. Owen. (*Complete in the Volumes for the years 1851, 1857, 1858, 1862, and 1864. Directions for the binding, Title-page, and Index, will be found in the Volume for the year 1864.*)
- The Reptilia of the Wealden and Purbeck Formations, by Professor Owen. (*Complete in the Volumes for the years 1853, 1854, 1855, 1856, 1857, 1858, 1862, and 1864. Directions for the binding, Title-pages, and Index, will be found in the Volume for the year 1864.*)
- The Reptilia of the Liassic Formations, by Professor Owen. (*Complete in the Volumes for the years 1859, 1860, 1863, 1869, and 1881. Directions for the binding, Title-pages, and Index, will be found in the Volume for the year 1881.*)
- The Fossil Mammalia of the Mesozoic Formations, by Professor Owen. (*Complete, with Title-page and Table of Contents, in the Volume for the year 1870.*)
- The Fossil Elephants, by Professor Leith Adams. (*Complete in the Volumes for the years 1877, 1879, and 1881. Directions for the binding, Title-page, and Index will be found in the Volume for the year 1881.*)

## 2. MONOGRAPHS in course of PUBLICATION :—†

- The Eocene Flora, by Mr. J. S. Gardner.  
 The Fossil Sponges, by Dr. G. J. Hinde.  
 The Crag Foraminifera, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady.  
 The Stromatopora, by Prof. H. Alleyne Nicholson.  
 Supplement to the Fossil Corals, by Dr. Duncan.  
 The Jurassic Gasteropoda, by Mr. W. H. Hudleston.  
 The Trilobites, by Dr. H. Woodward.  
 The Inferior Oolite Ammonites, by Mr. S. S. Buckman.  
 The Belemnites, by Professor Phillips.\*  
 The Sirenoid and Crossopterygian Ganoids, by Professor Miall.  
 The Fishes of the Carboniferous Formation, by Prof. Traquair.  
 The Fishes of the Old Red Sandstone, by Messrs. J. Powrie and E. Ray Lankester, and Professor Traquair.  
 The Reptilia of the Wealden Formation (Supplements), by Professor Owen.  
 The Reptilia of the Kimmeridge Clay, by Professor Owen.  
 The Reptilia of the Mesozoic Formations, by Professor Owen.  
 The Pleistocene Mammalia, by Messrs. Boyd Dawkins and W. A. Sanford.  
 The Cetacea of the Crag, by Professor Owen.

## 3. MONOGRAPHS which are in course of PREPARATION :—†

- The Fossil Cycadæ, by Mr. W. Carruthers.  
 The Rhizopoda of the Chalk, Chalk Marl, Gault, and Upper Greensand, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady.  
 The Foraminifera of the Lias, by Mr. H. B. Brady.  
 The Polyzoa of the Chalk Formation, by Mr. G. Busk.  
 The Carboniferous Entomostraca, Part II (Leperditidae), by Messrs. T. Rupert Jones, J. W. Kirkby, and G. S. Brady.  
 Supplement to the Tertiary and Cretaceous Entomostraca, by Prof. T. Rupert Jones.  
 The Wealden, Purbeck, and Jurassic Entomostraca, by Messrs. T. R. Jones and G. S. Brady.  
 The Cretaceous Mollusca (exclusive of the Brachiopoda), by the Rev. Prof. T. Wiltshire.  
 The Purbeck Mollusca, by Mr. R. Etheridge.  
 The Rhaetic Mollusca, by Mr. R. Etheridge.  
 The Carboniferous Bivalve Mollusca, by Mr. R. Etheridge, junr.  
 The Silurian Fish Bed, by Dr. Harley.

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\* Unfinished through the death of the Author, but will be continued by Mr. R. Etheridge.

† Members having specimens which might assist the authors in preparing their respective Monographs are requested to communicate in the first instance with the Honorary Secretary.

### § III. Dates of the Issue of the Yearly Volumes of the Palæontographical Society.

Volume	I	for 1847	was issued	to the	Members,	March, 1848.
"	II	" 1848	"	"	"	July, 1849.
"	III	" 1849	"	"	"	August, 1850.
"	IV	" 1850	"	"	"	June, 1851.
"	V	" 1851	"	"	"	June, 1851.
"	VI	" 1852	"	"	"	August, 1852.
"	VII	" 1853	"	"	"	December, 1853.
"	VIII	" 1854	"	"	"	May, 1855.
"	IX	" 1855	"	"	"	February, 1857.
"	X	" 1856	"	"	"	April, 1858.
"	XI	" 1857	"	"	"	November, 1859.
"	XII	" 1858	"	"	"	March, 1861.
"	XIII	" 1859	"	"	"	December, 1861.
"	XIV	" 1860	"	"	"	May, 1863.
"	XV	" 1861	"	"	"	May, 1863.
"	XVI	" 1862	"	"	"	August, 1864.
"	XVII	" 1863	"	"	"	June, 1865.
"	XVIII	" 1864	"	"	"	April, 1866.
"	XIX	" 1865	"	"	"	December, 1866.
"	XX	" 1866	"	"	"	June, 1867.
"	XXI	" 1867	"	"	"	June, 1868.
"	XXII	" 1868	"	"	"	February, 1869.
"	XXIII	" 1869	"	"	"	January, 1870.
"	XXIV	" 1870	"	"	"	January, 1871.
"	XXV	" 1871	"	"	"	June, 1872.
"	XXVI	" 1872	"	"	"	October, 1872.
"	XXVII	" 1873	"	"	"	February, 1874.
"	XXVIII	" 1874	"	"	"	July, 1874.
"	XXIX	" 1875	"	"	"	December, 1875.
"	XXX	" 1876	"	"	"	December, 1876.
"	XXXI	" 1877	"	"	"	February, 1877.
"	XXXII	" 1878	"	"	"	March, 1878.
"	XXXIII	" 1879	"	"	"	May, 1879.
"	XXXIV	" 1880	"	"	"	May, 1880.
"	XXXV	" 1881	"	"	"	May, 1881.
"	XXXVI	" 1882	"	"	"	June, 1882.
"	XXXVII	" 1883	"	"	"	October, 1883.
"	XXXVIII	" 1884	"	"	"	December, 1884.
"	XXXIX	" 1885	"	"	"	January, 1886.
"	XL	" 1886	"	"	"	March, 1887.

§ IV. SUMMARY OF THE MONOGRAPHS ISSUED TO THE MEMBERS (up to MARCH, 1887) : showing in the FIRST column whether each Monograph hitherto published be complete, or in the course of completion ; in the SECOND column, the yearly volumes which contain each particular Monograph (as a guide to binding the same) ; and in the FOURTH and following columns, the number of pages, plates, figures, and spectra described in the different Monographs.

I. SUBJECT OF MONOGRAPH.	II. Dates of the years for which the volume containing the Monograph was issued.	III. Dates of the years in which the Monograph was published.	IV. No. of Pages in each Monograph.	V. Plates in each Monograph.	VI. No. of Figures and Spectra described in the Text.	VII. No. of Copies of the Text.
The Morphology and Histology of Stigmatura ficoides, by Prof. W. C. Williamson, COMPLETE .....	1886	1887	66	15	91	1
The Eocene Flora, by Mr. J. S. Gardner and Baron Edttingshausen. Vol. I, COMPLETE .....	1879, 1880, 1882	1879, 1880, 1882	87	13	151	23
" " by Mr. J. S. Gardner. Vol. II, COMPLETE .....	1883, 1884, 1885	1883, 1884, 1886	159	27	400	31
The Flora of the Carboniferous Strata, by Mr. E. W. Binney, in course of completion .....	1867, 1870, 1871, 1875	1868, 1871, 1872, 1875	147	24	141	16
The Fossil Sponges, by Dr. G. J. Hinde, in course of completion .....	1886	1887	92	8	284	—
The Crag Foraminifera, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady, in course of completion .....	1865	1866	78	4	211	43
The Carboniferous and Permian Foraminifera, by Mr. H. B. Brady, COMPLETE .....	1876	1876	166	12	266	62
The Stromatopora, by Prof. Alleyne Nicholson, in course of completion .....	1855	1856	133	11	187	—
Tertiary, Cretaceous, Oolitic, Devonian, and Silurian Corals, by MM. Milne-Edwards and J. Hinde, COMPLETE (?) .....	1819, 1851, 1852, 1853, 1854	1850, 1851, 1852, 1853, 1855	466	72	800	319
Supplement to the Fossil Corals, by Prof. Dueron, in course of completion .....	1865, 1866, 1867, 1868, 1869, 1872	1866, 1867, 1868, 1869, 1870, 1872	232	49	707	149
The Polyzoa of the Crag, by Mr. G. Busk, COMPLETE .....	1857	1859	145	22	641	122
The Tertiary Echinodermata, by Prof. Forbes, COMPLETE .....	1852	1852	39	4	144	44
The Oolitic Echinodermata, by Dr. Wright. Vol. I, COMPLETE (?) .....	1855, 1856, 1857, 1858, 1878	1857, 1858, 1859, 1861, 1878	491	43	724	120½
" " Vol. II, COMPLETE .....	1861, 1864, 1880	1863, 1866, 1880	207	22	232	35
The Cretaceous Echinodermata, by Dr. Wright. Vol. I, COMPLETE .....	1862, 1867, 1869, 1870, 1872, 1873, 1875, 1878, 1881, 1882	1864, 1868, 1870, 1871, 1872, 1874, 1875, 1878, 1881, 1882	390	87	1119	113
The Fossil Cirripedes, by Mr. C. Darwin, COMPLETE .....	1851, 1854, 1858a	1851, 1855, 1861	137	7	320	54
The Fossil Merostomata, by Dr. H. Woodward, COMPLETE .....	1865, 1868, 1871, 1872, 1878	1866, 1869, 1872, 1873, 1878	265	36	365	51
The Post-Tertiary Entomostraca, by Mr. G. S. Brady, Rev. H. W. Crosskey, and Mr. D. Robertson, COMPLETE .....	1874	1874	237	16	515	134
The Tertiary Entomostraca, by Prof. Rupert Jones, COMPLETE .....	1855	1857	74	6	233	56
The Cretaceous Entomostraca, by Prof. Rupert Jones, COMPLETE .....	1849	1850	41	7	176	27
The Carboniferous Entomostraca, by Prof. Rupert Jones and Messrs. J. W. Kirby and Prof. G. S. Brady, Part I, COMPLETE .....	1874, 1884	1874, 1884	95	7	374	81
The Fossil Estherine, by Prof. Rupert Jones, COMPLETE .....	1860	1863	139	5	158	19½
		CARRIED FORWARD.....	3826	497		1500

SUMMARY OF THE MONOGRAPHS ISSUED TO THE MEMBERS (*up to MARCH, 1887*)—*continued.*

I. SUBJECT OF MONOGRAPH.	II. Dates of the Years for which the volume containing the Monograph was issued.	III. m. Dates of the Years in which the Monograph was published.	IV. No. of Pages in each Monograph.	V. No. of Plates in each Monograph.	VI. No. of Lithographed Figures and of Woodcuts.	VII. No. of Species described in the Text.
The Trilobites of the Cambrian, Silurian, and Devonian Formations, by Mr. J. W. Salter, COMPLETE	1862, 1863, 1864, 1866, 1883	1864, 1865, 1866, 1867, 1883	326	497	8329	1500
The Carboniferous Trilobites, by Dr. H. Woodward, COMPLETE	1883, 1884	1883, 1884	224	31	703	114
The Malacostracan Crustacea (comprising those of the London Clay, Gault, and Greensands), by Prof. T. Bell, in course of completion	1856, 1860	1858, 1863	86	10	148	31
The Fossil Brachiopoda, Vol. I. The Tertiary, Cretaceous, Oolitic, and Liassic Brachiopoda, by Mr. T. Davidson, COMPLETE	1850, 1852, 1853, 1854	1851, 1852, 1853, 1855	88	22	215	50
" " Vol. II. The Permian and Carboniferous Brachiopoda, COMPLETE	1856, 1857, 1858, 1859, 1860	1858, 1859, 1861, 1861, 1863	409	42	1855	160
" " Vol. III. The Devonian and Silurian Brachiopoda, COMPLETE	1862, 1863, 1865, 1866, 1868, 1870	1864, 1865, 1866, 1867, 1869, 1871	331	59	1909	157
" " Vol. IV. Supplements, Tertiary to Carboniferous, COMPLETE	1873, 1876, 1878, 1880, 1881, 1882	1874, 1876, 1878, 1880, 1881, 1882	528	70	2766	321
" " Vol. V. Supplements, Devonian and Silurian, COMPLETE	1882, 1883, 1884	1882, 1883, 1884	383	42	1654	215
" " Vol. VI. Bibliography, COMPLETE	1885	1886	476	21	1135	116
The Fossil Trigonina, by Dr. Lycett, COMPLETE	1872, 1874, 1875, 1877, 1879	1872, 1874, 1875, 1877, 1879	163	—	—	—
Supplement to the Fossil Trigonina, by Dr. Lycett, COMPLETE	1881, 1883	1881, 1883	246	41	446	115
The Mollusca of the Crag, by Mr. S. V. Wood:— Vol. I. (Univalves), COMPLETE	1847, 1853	1848, 1857	19	4	53	94
Vol. II. (Bivalves), COMPLETE	1850, 1853, 1855, 1858	1851, 1853, 1857, 1861	216	21	581	244
Supplements to the Crag Mollusca, No. I and II, by Mr. S. V. Wood, COMPLETE	1871, 1873, 1879	1872, 1874, 1879	344	31	691	253
" " No. III COMPLETE	1882	1882	322	18	517	232
The Eocene Mollusca, Cephalopoda and Univalves, by Mr. F. E. Edwards, continued by Mr. S. V. Wood. Vol. I. COMPLETE	1848, 1852, 1854, 1855, 1858, 1871	1849, 1852, 1855, 1857, 1861, 1877	24	1	20	13
The Eocene Mollusca, Bivalves, by Mr. S. V. Wood. Vol. I. COMPLETE	1859, 1862, 1870	1861, 1864, 1871	361	34	625	275
Supplement to the Eocene Mollusca, by Mr. S. V. Wood (Bivalves). Vol. I. COMPLETE	1877	1877	182	25	531	194
The Great Oolite Mollusca, by Prof. Morris and Dr. Lycett, COMPLETE	1850, 1853, 1854	1850, 1853, 1855	24	2	66	30
" " Supplement by Dr. Lycett, COMPLETE	1861	1863	282	30	846	419
The Jurassic Gastropoda, by Mr. W. H. Hudleston, in course of completion	1886	1887	129	15	337	194
The Inferior Oolite Ammonites, by Mr. S. S. Buckman, in course of completion	1886	1887	56	—	—	—
The Liassic Ammonites, by Dr. Wright, COMPLETE	1878, 1879, 1880, 1881, 1882, 1883, 1884, 1885	1878, 1879, 1880, 1881, 1882, 1883, 1884, 1886	24	6	28	3
The Balaenites, by Prof. Phillips, in course of completion	1863, 1864, 1866, 1868, 1869	1865, 1866, 1867, 1869, 1870	503	91	726	107
			128	36	622	69
		CARRIED FORWARD...	9374	1149	24,822	4821

I. SUBJECT OF MONOGRAPH.	II. Dates of the years for which the volume containing the Monograph was issued.	III. Dates of the years in which the Monograph was published.	IV. No. of Pages in each Monograph.	V. No. of Plates in each Monograph.	VI. No. of Engravings in each Monograph.	VII. No. of Species described in the Text.
		BROUGHT FORWARD...	3374	1149	24,822	4821
The Upper Cretaceous Cephalopoda, by Mr. D. Sharpe, COMPLETE.	1853, 1854, 1855	1853, 1855, 1857	67	27	319	79
The Fossils of the Permian Formation, by Prof. King, COMPLETE.	1849, 1851e	1850, 1855	287	29	511	138
The Sirenoid Ganoïds, by Prof. Miall, in course of completion	1878	1878	32	6	61	6
The Fishes of the Carboniferous Formation, by Dr. Traquair, in course of completion	1877	1877	60	7	58	5
The Fishes of the Old Red Sandstone, by Messrs. J. Powrie and E. Ray Lankester, in course of completion	1867, 1869	1868, 1870	62	14	195	21
The Reptilia of the London Clay [and of the Brecklesham and other Tertiary Beds], by Prof. Owen and Bell, Vol. I., COMPLETE †.	1848, 1849, 1856f	1849, 1850, 1859	150	58	304	39
" " Vol. II., Part I, by Prof. Owen, in course of completion	1880	1880	4	2	4	1
The Reptilia of the Cretaceous Formations, by Prof. Owen, COMPLETE ‡.	1851, 1857, 1858, 1862	1851, 1859, 1861, 1864	184	59	519	26
The Reptilia of the Wealden and Purbeck Formations, by Prof. Owen, COMPLETE ‡.	1853, 1854, 1855, 1856, 1857, 1858, 1862	1853, 1855, 1857, 1858, 1859, 1861, 1864	155	62	251	17
The Reptilia of the Wealden Formations (Supplements) in course of completion	1871, 1873, 1876, 1878, 1879	1872, 1874, 1876, 1878, 1879	81	21	175	15
The Reptilia of the Kimmeridge Clay Formation, by Prof. Owen, in course of completion	1859, 1860, 1868	1861, 1863, 1869	16	6	23	3
The Reptilia of the Liassic Formations, by Prof. Owen, COMPLETE	1859, 1860, 1863, 1869, 1881a	1861, 1863, 1865, 1870, 1881	174	50	276	20
The Reptilia of the Mesozoic Formations, by Prof. Owen, in course of completion	1873, 1875, 1877	1874, 1875, 1877	97	24	165	17
The Crag Cetacean, by Prof. Owen, in course of completion	1869	1870	40	5	43	7
The Fossil Elephants, by Prof. Leith Adams, COMPLETE.	1877, 1879, 1881a	1877, 1879, 1881	205	28	216	3
The Pleistocene Mammalia, by Messrs. W. Boyd Dawkins and W. A. Sanford, in course of completion	1864, 1867, 1868, 1871, 1878, 1886	1866, 1868, 1869, 1872, 1878, 1887	333	39	340	12
The Mammalia of the Mesozoic Formations, by Prof. Owen, COMPLETE	1870	1871	115	4	247	30
		TOTAL.....	11,406	1590	28,529	5260

a Index. b Title-page to Univalves. c Note to Crag Mollusca. d Contains the Permian. e Two corrections of Plates. f Supplement.  
 g Many of the species are described, but not figured. h British species only reckoned. i British species only reckoned. k A Supplement is now in course of publication.  
 i Index will be published in 1878. j Marked on outside label 'Reptilia of Oolitic Formations.'

§ V. STRATIGRAPHICAL TABLE *exhibiting the BRITISH FOSSILS already figured and described in the ANNUAL VOLUMES (1847—1886) of the PALEONTOGRAPHICAL SOCIETY.*

	P L A N T S.	PROTOZOA.		RADIATA.		ARTICULATA.					
		Sponges.	Foraminifera.	Stromatoporoidea and Corals.	Echinodermata.	Cirripedes.	Cypridae, Cytherinae, &c.	Estheria.	Merostomata.	Trilobites.	Malacostracous Crustacea.
Pleistocene .....	...	...	...	...	.....	.....	1874				
Crag .....	...	...	1865	1849	1852	{ 1851 1854 }					
Eocene .....	{ 1879 1880 1882 1883 1884 1885 }	...	...	{ 1849 1865 }	1852	{ 1851 1854 }	1853	...	.....	.....	1856
Cretaceous.....	...	...	...	{ 1849 1868 1869 }	{ 1862 1867 1869 1870 1872 1873 1875 1878 1881 1882 }	{ 1851 1854 }	1849	...	.....	.....	1860
Wealden .....	...	...	...	...	.....	.....	...	1860			
Oolitic .....	...	...	...	{ 1851 1872 }	{ 1855, 1856, 1857, 1858, 1861, 1878, 1880 }	{ 1851 }	...	1860			
Liassic .....	...	...	...	{ 1851 1866 1867 }	{ 1855, 1856, 1858, 1861, 1864 }						
Triassic .....	...	...	...	...	1880	.....	...	1860			
Permian .....	1849	1849	{ 1849 1876 }	{ 1849 1852 }	1849	.....	1849	1860			
Carboniferous...	{ 1867 1870 1871 1875 1886 }	...	1876	1852	.....	.....	{ 1874 1884 }	1860	{ 1872 1878 }	1883, 1884	
Devonian .....	...	...	...	{ 1853 1885 }	.....	.....	...	1860	{ 1865 1868 1872 1878 }	1862	
Silurian .....	...	1886	...	{ 1854 1885 }	.....	.....	...	...	{ 1868 1871 1872 1878 }	{ 1862, 1863, 1864, 1866 }	
Cambrian .....	...	1886	...	...	.....	.....	...	...	.....	1864	

NOTE.—The numbers in the above List refer to the Volumes issued for those Dates.



STRATIGRAPHICAL TABLE *exhibiting the BRITISH FOSSILS already figured and described in the ANNUAL VOLUMES (1847—1886) of the PALEONTOGRAPHICAL SOCIETY (continued).*

	MOLLUSCA.				VERTEBRATA.		
	Polyzoa.	Brachiopoda.	Monomyaria, Dinomyaria, and Gastropoda.	Cephalopoda.	Fishes.	Reptiles.	Mammalia.
Pleistocene .....	...	1873	.....	...	...	.....	1864 1867 1868 1871 1877 1878 1879 1881 1886
Crag .....	1857	{ 1852 1873 1879 }	{ 1847, 1850, 1853, 1855, 1871, 1873, 1879, 1882 1852, 1854, 1855, 1858, 1859, 1862, 1870, 1877 }	...	...	.....	{ 1869 1881 }
Eocene .....	...	{ 1852 1873 }	{ 1852, 1854, 1855, 1858, 1859, 1862, 1870, 1877 }	1848	...	1848, 1849, 1856, 1880	
Cretaceous .....	...	{ 1852, 1854, 1873, 1884 }	{ 1872 1875 1877 1879 }	{ 1853 1854 1855 }	...	{ 1851, 1857, 1858, 1862 1853, 1854, 1855, 1856, 1857, 1862, 1871, 1873, 1875, 1876, 1878, 1879 (Purbeck) 1853, 1858 (Kim. Clay), 1859, 1860, 1868, 1873, 1875, 1877 (Great Oolite) 1875 }	
Wealden .....	...	... ..	.....	...	...		
Oolitic .....	...	{ 1850, 1852, 1876, 1878, 1884 }	{ 1850, 1853, 1854, 1872, 1874, 1875, 1877, 1879, 1883, 1886 }	{ 1850 1861 1868 1869 1886 }	...		1870
Liassic .....	...	{ 1850, 1852, 1876, 1878, 1884 }	{ 1874, 1877, 1879, 1883 }	{ 1863, 1864, 1866, 1868, 1878, 1879, 1880, 1881, 1882, 1883, 1884, 1885, }	...	{ 1859, 1860, 1863, 1869, 1873, 1881 }	
Triassic .....	...	1876, 1878	1879	.....	1878	.....	1870
Permian .....	1849	{ 1849, 1856, 1880 1856, 1857, 1858, 1859, 1860, 1880, 1884 1862, 1863, 1881, 1882, 1884 1865, 1866, 1868, 1870, 1881, 1882, 1883 }	1849	1849	1849	1849	
Carboniferous ...	...	{ 1856, 1857, 1858, 1859, 1860, 1880, 1884 1862, 1863, 1881, 1882, 1884 1865, 1866, 1868, 1870, 1881, 1882, 1883 }	.....	.....	1877		
Devonian .....	...	{ 1862, 1863, 1881, 1882, 1884 1865, 1866, 1868, 1870, 1881, 1882, 1883 }	.....	.....	{ 1867 1869 }		
Silurian .....	...	{ 1865, 1866, 1868, 1870, 1881, 1882, 1883 }					
Cambrian .....							

NOTE.—The numbers in the above List refer to the Volumes issued for those Dates.







THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

VOLUME FOR 1886.

L O N D O N

MDCCCLXXXVII.



A MONOGRAPH

ON THE

MORPHOLOGY AND HISTOLOGY

OF

STIGMARIA FICOIDES.

BY

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OWENS COLLEGE AND THE VICTORIA UNIVERSITY, MANCHESTER.

PAGES i—iv, 1—62; PLATES I—XV.

LONDON:

PRINTED FOR THE PALEONTOGRAPHICAL SOCIETY.

1887.

PRINTED BY  
ADLARD AND SON, BARTHOLOMEW CLOSE.



## INTRODUCTION.

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A PALÆONTOLOGIST, located for more than half a century near the centre of an area throughout which the Carboniferous rocks predominate, I have necessarily been brought into constant contact with various forms of *Stigmaria ficoides*. Notwithstanding these advantages I long participated in the ignorance which prevailed so widely respecting them; but the discovery, especially in the districts round Oldham and Halifax, of those remarkable coal-seams overlying the Millstone Grit, from which such rich harvests have been reaped during the last twenty years, has materially altered the position of students of *Stigmaria*. During that period, I have collected every fragment of the plant calculated to throw light upon its structure and affinities, and I think I may express my belief that my cabinets now contain the largest collection of such illustrative specimens in existence.

Under the impression that I now possess the materials for drawing up a history of *Stigmaria ficoides* which would contain but few blank places, the time seems to have arrived for placing such a history in the hands of geologists, though there are, even yet, some features of the organism respecting which we require more knowledge. The publication of a fair report of what we do know will probably facilitate the acquisition of what is yet wanting. I am fully satisfied that *Stigmaria*, viewed as an *organ*,<sup>1</sup> is a root; I am equally so that it is the root of various species of *Sigillaria* and *Lepidodendra*. Hence it is far from improbable that specific differences may one day be found amongst the objects which we now know by the name of *Stigmaria ficoides*; but at present we have wholly failed to discover any such differences.

Though our knowledge of the structure of the aerial stems of *Sigillariæ* and *Lepidodendra* is steadily increasing, we yet require more than is at present within our reach; but this is already sufficient to correlate, with a fair measure of probable accuracy, the relationship existing between the tissues of these aerial stems and those of their *Stigmarian* roots. We have abundant evidence respecting the external features of that relationship, but we have yet to discover the actual junction of the vascular, exogenous or centrifugally developed, cylinder of the root with

<sup>1</sup> I employ this term as it is used by Prof. De Bary, *i.e.* as the instrument of physiological work. See 'Comparative Anatomy of the Phanerogams and Ferns,' English Translation, p. 1.

the corresponding cylinder in the aerial stems. The centrifugal cylinder of the latter must obviously have been continuous with the similar one of the root, but the centripetal zone enclosed within the centrifugal zone obviously terminated at the base of the stem, like the medullary sheath of an ordinary exogen. But how it does so yet awaits demonstration. Connected with this another problem arises. Judging from the specimens in our possession I should conclude that the diameter of the vascular cylinder of a *Stigmaria* was about one fourth that of its entire diameter, including its surrounding bark. The largest vascular cylinder I have yet seen is recorded in my text as being  $\frac{19}{16}$  of an inch in diameter, which would give to the root of which it was the centre, a diameter of about  $4\frac{3}{4}$  inches, or a circumference of rather more than 14 inches. But in the text I have described roots, the proximal ends of which are more than three feet in circumference. Now, such roots, according to the scale of proportions adopted above, would require a vascular cylinder fully three inches in diameter. We have not yet found any that approach this magnitude. We have yet to discover whether or not any roots of this size exist, the internal structure of which has been preserved. Unfortunately little more than the outermost bark remains either in stems or roots of these dimensions. Then we want specimens showing the structure of the part of the cortex internal to the prosenchymatous layer, which latter forms so conspicuous a feature alike in the *Stigmarian* roots and in their aerial stems. We are familiar with the parenchymatous zone that occupies this position in the stems, and we have indications that the same parenchyma was continued into the root; but we want clearer evidence than we yet possess whether or not such was the case.

It must further be borne in mind that all the numerous Carboniferous plants, great and small, had rootlets of some kind, and that some of them bear a superficial resemblance to those of *Stigmaria*. This is especially the case with the rootlets of the plant which I named *Amyelon*, yet none of these can well be mistaken for those of *Stigmariæ*, though I doubt not that some have been so mistaken.

Some readers may consider that I have dwelt needlessly upon minute details of structure which, in their opinion, have neither interest nor importance. This is possible; yet I have done so with a definite hope as well as with an object. The hope is that sooner or later we shall know more than we yet do of the morphological and physiological links connecting the primæval forms of vegetation with their living representatives. No real facts, however small, can be absolutely worthless to the botanist who strives to work out this subject. Anyhow, the faithful record of them can do no harm, and they may be found useful at some future time.

Two peculiarities may be observed in the form of this Monograph. One is the elaboration of the Index to the Plates. In studying the works of some of our most distinguished Botanists, I have found it difficult to discover in what part of the text the detailed descriptions of the Plates were to be found, and the too brief refer-

ences in the Index itself threw but little light upon the subject. I have endeavoured as far as possible to make this task easy to such students as may consult what I have written. A second feature is equally important. My entire Cabinet of sections of these Carboniferous plants, of which a very elaborate descriptive catalogue is already prepared, is destined to find its ultimate home in the Botanical Museum of the Owens College, where it will be accessible to any palæontologist who may desire to consult it. In the catalogue referred to, the description of each specimen embodies a statement as to what, in my opinion, that specimen teaches or proves. The result will be that, whether those who may follow me in these researches agree with my views or feel compelled to reject them, they can themselves examine the specimens upon which those views were based. In order to make such references easy, so far as the present work is concerned, the Cabinet number of each specimen figured is attached to the notice of each figure in the Index to the Plates. The cases where no such numbers are recorded belong to specimens not in my cabinet. Such examples, however, are extremely few, nearly all the specimens figured being in my own possession.

Stigmariæ, which are mere casts or impressions, no portion of their internal organisation being preserved, are widely, and often abundantly, diffused through the entire series of the Upper Carboniferous Rocks of Lancashire and Yorkshire down to the Millstone Grit. But the beds, from which specimens, not only of Stigmariæ, but of numerous other plants having their internal structures exquisitely preserved have been mainly derived, are the thin, lowermost coal-seams of the Ganister series. These plants occur in nodules, of various diameters from a foot downwards, which are embedded in the substance of the coal. In some localities these nodules are so numerous as to make the working of the coal-seam unprofitable; a fact unfortunate for the palæontologist, since such commercially unprofitable collieries are liable to be closed. So far as the Lancashire seams in which these plant-bearing nodules occur are concerned, an excellent summary of them will be found in Mr. Binney's 'Memoir on Calamites and Calamodendron.'<sup>1</sup> For the following detailed section of the corresponding series of deposits in the Halifax district I am indebted to my friend J. W. Davis, Esq., F.G.S., of Chevinedge, Halifax.<sup>2</sup>

<sup>1</sup> Palæontographical Society's volume for 1867.

<sup>2</sup> It is fortunate for geological science that similar deposits have now been discovered at three separate localities on the Continent. One of these is at Pith Vollmond, in Westphalia, where my friend, Count de Solms, tells me he finds in great abundance *Lepidodendron selaginoides*, *Lyginodendron Oldhamium*, and *Rachiopteris aspera*, as well as examples of *Amylon radicans* and some other well-known Yorkshire and Lancashire forms. One of the remaining two is in the Banat, in South Hungary, and the other in Moravia. In all these places the deposits appear to be of the same age as those of Yorkshire and Lancashire, each being also overlain by a bed containing the marine *Aviculopecten*, as in our Ganister series; it is from these shells, along with other mollusks, that the lime, which has played so important a part in the preservation of our plants, has been derived.

## INTRODUCTION.

	Ft. In.		Ft. In.
Elland Flagrock—Flags . . .	45 0	Laminated Shale with <i>Aviculopecten</i> .	0 4
Shale . . .	35 0	<i>Hard Bed or Ganister Coal</i> , containing	
Flag . . .	120 0	concretions of Carb. of Lime, and	
Shale . . .	80 0	of Iron-pyrites, both with vegetable	
<i>Eighty yards Band Coal (or Upper Band</i>		remains in fine preservation . .	2 2
<i>Coal)</i> . . .	0 6	Ganister Rock . . .	1 0
Eighty yards Band Rock . . .	15 0	Seat-earth . . .	5 0
Black Shales . . .	80 0	Shale . . .	25 0
<i>Hard Bed Band Coal (Forty-eight yards</i>		<i>Middle Band Coal or Clay Coal</i> . .	0 6
<i>Coal)</i> . . .	1 2	Middle Band Rock . . .	12 0
Shales with Ironstone . . .	35 0	Shales . . .	50 0
<i>Thirty-six yards Band Coal</i> . . .	1 0	<i>Soft Bed Coal</i> . . .	1 6
Fire-clay or Galliard . . .	1 6	Seat-earth . . .	2 0
Shale with thin Sandstones . . .	95 0	Sandstone . . .	20 0
Shale containing concretions of Carb.		Shale . . .	80 0
of Lime with covering of Iron-pyrites.		<i>Thin Coal</i> . . .	0 6
Full of <i>Goniatites</i> , <i>Nautilus</i> , <i>Ortho-</i>		Seat-earth . . .	5 0
<i>ceras</i> , <i>Nucula</i> , <i>Aviculopecten</i> , &c. .	5 0	Rough Rock . . .	

It now only remains to record my acknowledgments of the assistance I have received from many friends in accumulating the materials from which this monograph has been drawn. All such names as Mr. G. Wild, of the Bardsley Colliery at Ashton-under-Lyne, Mr. J. Spencer, and Mr. Binns, of Halifax, Mr. Isaac Earnshaw and Mr. Neild, of Oldham, Mr. J. Butterworth, of Shaw, and Mr. Ward, F.G.S., of Langton, in Staffordshire, are already well known to those who are familiar with my memoirs contained in the 'Philosophical Transactions.' The cabinet of my late friend, Mr. John Aitken, now in my possession, has furnished me with some interesting facts. All the persevering collectors thus catalogued have poured their treasures into my lap with a generosity that is alike significant of their desire to facilitate my researches and to aid in the advancement of science. I am also indebted to Professor Miall and Professor Green, of Leeds, to Professor Lebour, of Newcastle-upon-Tyne, and to Mr. Geddes, of Blackburn, for similar assistance. The Natural History Society of Newcastle-upon-Tyne also has kindly granted me the loan of several interesting specimens from the Hutton Collection, now in its possession. But I must especially mention Mr. W. Cash, F.G.S., of Halifax, whose unwearied diligence in accumulating new material for investigation has rendered me the greatest service. If I have been in any degree successful in removing some of the clouds which have hitherto obscured the history of *Stigmaria ficoides*, no small measure of that success is due to the friends who have generously assisted me to accumulate the rich store of materials to which my attention has so long been given.

# A MONOGRAPH

ON

## STIGMARIA FICOIDES.

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FEW of the objects studied by Palæontologists have occasioned more speculation than those fragments of Carboniferous vegetation long known by the names of Variolaria, Phytolithus, and Ficoidites, but now recognised by that of *Stigmaria ficoides* assigned to them by Adolphe Brongniart.<sup>1</sup> The opinions formed respecting their botanical nature and relationship have varied even more than their names. For more than half a century nothing could be learnt respecting them beyond what their external contours could teach; and, since many misunderstood causes combined to modify those contours, most of the opinions formed respecting them had no value. But much light has been thrown upon these fossils during the last half century. Nevertheless, even at the present time some eminent Palæontologists continue to give circulation to views respecting them which are, in my opinion, altogether inconsistent with what, to British geologists, are well-known facts. Some of these views are reproductions of what we might have hoped were exploded errors. Others are new, but apparently no truer than the older ones.

To catalogue the vague guesses promulgated respecting *Stigmaria* in earlier days would be wasted labour. But the case is altered when we find such distinguished leaders of the French school of Palæo-botanists, as M. Renault, M. Grand-Eury, the Marquis de Saporta, and M. Marion giving currency to what I believe to be serious errors, alike of observation and of interpretation, relating to the *Stigmaria ficoides* of Brongniart. It happens that the Coal-Measures of Great Britain, Canada, and the United States of America are rich beyond most other countries in the supply they afford of specimens of this plant. This is true not only of the structureless examples known to our forefathers, but of others in which the internal structure is preserved with exquisite beauty and completeness. Hence the rich stores contained in our cabinets enable us to speak with a decision that

<sup>1</sup> 'Prodrome d'une Histoire des Végétaux Fossiles,' Paris, 1828.

would otherwise appear presumptuously dogmatic. My reasons for rejecting the views of my French fellow-workers will be given in the following pages. But in order to avoid needless interruptions to the continuity of my descriptions of what appear to me to be facts, and of the conclusions which I think legitimately deducible from those facts, all controversial treatment of the subject will be limited to the footnotes.

I have not thought it necessary to re-figure the common aspects of *Stigmaria ficoides* with its attached rootlets. Every geologist is familiar with these forms; such figures have been well supplied by Martin,<sup>1</sup> under the name of *Phytolithus verrucosus*; by Artis<sup>2</sup> as *Ficoidites furcatus, verrucosus, and major*; by Lindley and Hutton<sup>3</sup> and by Corda<sup>4</sup> as *Stigmaria ficoides*.

The first acquisition of some really scientific notions respecting *Stigmaria* date from the publication of a memoir by Mr. (now Sir John) Hawkshaw, the distinguished engineer. When constructing the railway between Manchester and Bolton, in 1837, under Sir John Hawkshaw's direction, some excavators, cutting through the Carboniferous strata at Dixon Fold, near the present Clifton Station, discovered a huge fossil tree with large out-spreading roots, standing vertically upon a seam of coal, and soon afterwards they exposed several others in similar positions. Excellent figures and descriptions of five of these trees were published by Sir John Hawkshaw in 1839.<sup>5</sup> The largest of them was eleven feet high, seven and a half feet in circumference round its top, and fifteen feet round its base. A second less lofty tree exhibited four large roots radiating from its base; each of these roots soon divided, producing eight secondary roots which extended six feet from their parent stem. All these fossils were coated externally with a layer of coal from a quarter to three quarters of an inch in thickness. Within this coal each stem and root was merely a structureless mass of clay or shale. The outer surface of the coal, as well as the corresponding one of the subjacent clay, exhibited irregular longitudinal flutings, but these surfaces afforded no definite evidence respecting the character of the trees. This discovery established several very important facts, first, that some of the largest stems of trees found in the Coal-Measures were furnished with gigantic roots, which branched dichotomously; and second, that these roots must have extended downwards through a bed of undisturbed coal ten inches thick, by which the roots were abruptly cut off. It became obvious that the trees must have grown where the fossils stood, and that the materials converted into the bed of coal must have accumulated above their wide-spreading roots whilst those trees were growing, and that subsequent changes obliterated parts of the roots.

<sup>1</sup> 'Petrificata Derbiensia.'

<sup>2</sup> 'Antediluvian Phytology.'

<sup>3</sup> 'Fossil Flora of Great Britain,' vol. i.

<sup>4</sup> 'Flora der Vorwelt.'

<sup>5</sup> 'Trans. Geol. Soc. London,' 2nd ser., vol. vi, p. 173, plate xvii.

The second significant discovery was recorded by the late Mr. Binney.<sup>1</sup> Some trees, similar in most respects to those of Dixon Fold, were laid bare at St. Helens, in Lancashire, from which Mr. Binney learnt two important truths; first, that some of these trees were true *Sigillariæ*; and second, that their roots were the long-discussed *Stigmaria*. A second discovery of a similar kind was made at Duckenfield, in Lancashire, in the colliery of Messrs. Swire, Lees, and Co., where a short stem was exposed, from one side of which a large root issued. This root, which was three feet and one inch in circumference, ran horizontally for about sixteen inches, when it divided into two branches, each of which again divided. The result of these bifurcations was the production of four smaller roots, none of which underwent further subdivision, though one of them was prolonged to a distance of fifteen feet from the parent stem; in their proximal proportions the surfaces of these roots exhibited no *Stigmarian* features, but such were abundantly displayed beyond their second ramifications. Mr. Binney was again the recorder of this most important discovery.<sup>2</sup>

Our next evidence showing that *Stigmaria* was a root of a large tree, and not an independent plant, came from across the Atlantic. Mr. Richard Brown reported<sup>3</sup> the discovery, in the Coal-field of Sydney, Cape Breton Island, of trees similar to those observed in England; and a little later he pointed out, in addition, that whilst some of these trees were undoubtedly *Sigillariæ*, amongst them was what he believed to be a *Lepidodendron*,<sup>4</sup> whose roots were equally *Stigmarian*, a fact which has been confirmed by various later observers. Mr. Brown estimated that the spreading roots of one of his trees must have covered two hundred square feet of ground. That the roots of *Lepidodendron* were *Stigmarian* was observed by Geinitz on the Continent, and by other observers in the Coal-fields of South Wales. A few years ago a remarkable Carboniferous forest was laid bare close to Oldham, in Lancashire, in which some of the trees were unmistakably *Lepidodendron* with *Stigmarian* roots.<sup>5</sup>

Nothing whatever was known of the internal structure of *Stigmaria* until 1838, when Mr. (now Professor) Prestwich obtained a specimen from the Coal-field of Colebrook Dale, of which a transverse and a tangential section were figured in the

<sup>1</sup> 'London, Edinburgh, and Dublin Philosophical Magazine,' series 3, vol. xxiv, p. 105, 1844.

<sup>2</sup> 'Quarterly Journal of the Geological Society of London,' vol. ii, 1846.

<sup>3</sup> 'Quarterly Journal of the Geological Society of London,' vol. iv, p. 46.

<sup>4</sup> Whether or not Mr. Brown was right in concluding that the plant in question was a *Lepidodendron* is unimportant, since we now possess abundant evidence that the root of *Lepidodendron* as well as of *Sigillaria* was a *Stigmaria ficoides*.

<sup>5</sup> In some of his memoirs Mr. Binney contended that the *Halonixæ* were the roots of *Lepidodendron*. It is now clear that these were the fruit-bearing branches of *Lepidodendron*—not its roots. M. Renault and M. Grand-Eury have contended that the *Stigmaria* are not always roots but rhizomes, which have leaves, and send up aerial stems from their peripheral extremities. The absolute absence of all foundation for these opinions will be shown on a later page.

'Fossil Flora of Great Britain.'<sup>1</sup> The former of these sections (loc. cit., fig. 1) is, as far as it goes, a fair representative of such sections of the plant; but the other, fig. 2, is wholly unintelligible to me. A much more accurate use of the same specimen was made by Professor Prestwich himself who figured and described additional sections of it in his classical memoir on the 'Geology of Colebrook Dale.'<sup>2</sup> He was indebted to the late Robert Brown for the accurate suggestion that certain vascular bundles, springing from the vascular axis figured, terminated at the depressed external tubercles so characteristic of all specimens of *Stigmaria*. The existence of these bundles had escaped the notice of the authors of the 'Fossil Flora,' though they certainly ought to have represented them in their fig. 2, as they were illustrated in corresponding sections in Professor Prestwich's memoir.

A memoir 'On Some Peculiarities in the Structure of *Stigmaria*,' by Sir Joseph Hooker, appeared in 1848.<sup>3</sup> The author, in this memoir, recorded all that was then known about *Stigmaria*. But at that time illustrative materials were few, and too often inconclusive. Some equally imperfect specimens previously described by Professor Göppert<sup>4</sup> misled Dr. Hooker as to the origin of the vascular bundles noticed by Robert Brown, as they afterwards misled Mr. Binney. In 1858 the latter author figured and described the central portion of a *Stigmarian* rootlet,<sup>5</sup> and in a second memoir<sup>6</sup> he republished the same figure, and along with it he represented the fragment, from the interior of which his section of the rootlet had been obtained. This fragment was misinterpreted by Binney exactly as a similar specimen had previously been by Göppert.

Parts II and XI of my memoirs on the "Organisation of the Fossil Plants of the Coal-Measures"<sup>7</sup> contain some hitherto undescribed features in the structure of *Stigmaria*, as well as diagrammatic restorations both of that structure and of the organic relations of the root to its *Lepidodendroid* and *Sigillarian* stems; those restorations need little, if any, alteration to adapt them to the present state of our knowledge, though during the subsequent years a large amount of information has been obtained respecting the details of the organisation of *Stigmaria*.

On examining the trees discovered at Dixon Fold, it soon became obvious that the shaly materials of which they were composed would give way, however carefully they might be protected from the weather. Hence an Italian artist named

<sup>1</sup> Vol. iv, p. 166.

<sup>2</sup> 'Transactions of the Geological Society of London,' 2nd series, vol. v, Pl. 38.

<sup>3</sup> 'Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology in London,' vol. ii, part 2, 1848.

<sup>4</sup> 'Les Genres des Plantes Fossiles.' Bonn, 1841.

<sup>5</sup> 'Quarterly Journal Geol. Soc.,' vol. xv, p. 76.

<sup>6</sup> 'Observations on the Structure of Fossil Plants found in the Carboniferous Strata,' part iv, "*Sigillaria* and *Stigmaria*," *Palaontographical Society's* vol. for 1875.

<sup>7</sup> 'Phil. Trans.,' 1872 and 1881.



Bally, well skilled in the art of making moulds, was employed to obtain exact casts of the two most important of the above trees. These casts, which are now preserved in the Geological Museum of Owens College, are represented in Figs. 1 and 2. That represented by Fig. 1 is 2 feet 6 inches high. The circumference of its upper extremity is 7 feet 9 inches, and 8 feet 5 inches at two feet from the floor. From \* to \* measures 10 feet. Though the full length of the spreading roots which originally existed is not exhibited in either of these casts, both well show some of their primary dichotomous ramifications. The specimen, Fig. 2, is  $6\frac{1}{2}$  feet high; its circumference at its upper extremity is 7 feet 10 inches, and 10 feet 6 inches at two feet above the floor. The longitudinal ridges and furrows seen on these casts do not represent the vertical flutings of a *Sigillaria*, neither do we find on the roots any traces of the rootlet-scars so conspicuous in Figs. 5 and 6. We learn from the specimen, Fig. 2, that in all probability no portion of the true aerial stem is preserved in Fig. 1. It is a mere mass of coalesced roots. The upper part of Fig. 2 is doubtless cauline. The disappearance of all traces of leaf-scars from the latter, and of rootlet-scars from both, is due to the same cause, viz. the internal exogenous growth, which increased the diameter alike of the vascular and cortical zones of both stem and root. This expansion necessarily caused the outer bark to become fissured and its superficial portions to be thrown off; and, since the cicatrices left by both leaves and rootlets were confined to the superficial cortex, when this was cast off they inevitably disappeared along with it. This gradual disappearance of both can readily be traced in numerous specimens.

As is now well known, the primary roots given off by all these trees are four in number. Fig. 1 only exhibits two (*a, a*) of them. Three such (*a, a, a*) are seen in Fig. 2. In Fig. 1 both the primary roots, *a, a*, dichotomise. In Fig. 2 only one such dichotomy is seen at *a'*, but as the tree originally stood at Dixon Fold more such were visible.

The thickness of each primary root (*a*) is often enormous in the older trees. The tetramorphic arrangement is best seen when the specimens are inverted so as to show their inferior surfaces. Plate II, fig. 3, represents one such base now in the Museum of the Leeds Literary and Philosophical Society.<sup>1</sup> Such specimens are frequently marked by the defined crucial suture seen in Figs. 4 and 6, a fact which was first pointed out by Mr. Binney in 1854.<sup>2</sup> These sutures indicate the surfaces of contact of the four several roots. In Fig. 3 they are very feebly preserved. The circumference of the root *a* at *e-h* is 3 feet; of *b* at *e-g* is 3 feet 2 inches; the breadth from *g* to *h* is 21 inches, and from *e* to *f* 18 inches, whilst from *a* to *d* is  $37\frac{1}{2}$  inches.

<sup>1</sup> This figure is lithographed from a photograph, for which I am indebted to Professor Miall, the accomplished Curator of the Museum. Figs. 1 and 2 are also lithographed from photographs taken for me by A. Brothers, Esq., F.R.A.S., of Manchester.

<sup>2</sup> 'Quarterly Journal of the Geological Society,' vi, p. 21, figs. 5 and 7.

Pl. II, fig. 4, represents a fine specimen in Professor Green's collection at the Leeds College of Science.<sup>1</sup> This specimen measures 50 inches from *a* to *b* and 36 from *c* to *d*. Though marked as usual by longitudinal cracks and corrugations, its surface is smooth contrasted with that of Fig. 3. The lines of demarcation between the four roots are not exactly crucial, as is also the case in Plate II, fig. 6. The growth of two, *a* and *b*, has probably been a little in advance of that of the other two, which seem to have been pushed asunder by the former. Another striking feature in this specimen is the length attained by each of the four roots, especially by *a*, without dichotomising. This variability in the conditions of these roots in different individuals was probably dependent on local states of the soil into which the roots had to penetrate. An instructive illustration of this probability is afforded by Mr. Binney in his description of the Duckinfield specimen, now in the Owens College Museum; one of the primary roots, 3 feet and 1 inch in circumference, extended horizontally for sixteen inches, when it divided into two secondary branches; each of these again divided into two others, one of which ran horizontally to a distance of fifteen feet from the central stem, without any further subdivision. These four ultimate branches alone exhibited the rootlet-scars characteristic of *Stigmara*. On the other hand, the St. Helen's tree presented a very different appearance. Its primary roots penetrated the fireclay at angles, varying from 50° to 60°, before assuming the horizontal direction. In the former case the roots encountered a stiff clay, which they did not penetrate freely; those of the latter example had eight feet of silty clay beneath them, into which they plunged more easily.

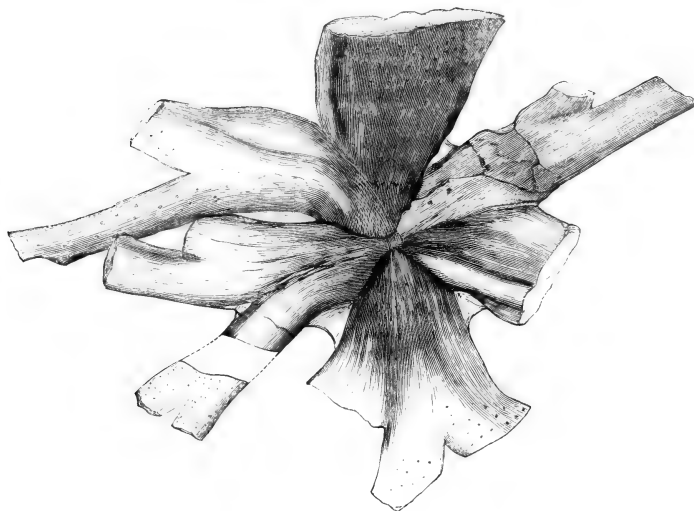
Plate III, figs. 5 and 6, represent an instructive specimen sent to me by Mr. Geddes, the Librarian of the Blackburn Free Library. Being the base of a much younger tree than any hitherto described, it illustrates one or two points of interest not seen in any other example that I am acquainted with. The entire surface of the specimen being covered with the characteristic rootlet-scars, it is obvious that it consists wholly of four coalesced roots, no portion of the true aerial stem remaining in connection with it. It further demonstrates that the absence of all traces of the rootlet-scars from most of the large specimens is due, as I have already suggested, to superficial decortication and not to their previous non-existence. A comparison of the general outline of Fig. 5 with that of Fig. 1 suggests, as already remarked, that the latter example also represents roots only. The maximum height of Fig. 5 above the table, when standing upon its four rootlets, is only 6 inches; the diameter of its upper extremity, *a*, is about 6 inches. From *c* to *d* it measures 10 inches. The mean diameter of the broken end of the root *d* is slightly more than  $2\frac{1}{4}$  inches, the corresponding part of *c* being  $2\frac{1}{2}$  inches. The diameter of the root *d*

<sup>1</sup> This figure is lithographed from a drawing made for me by Miss Beatrice Boyle, of Leeds, who promises to become a valuable auxiliary to scientific investigators who are not themselves artists.

at its base, from *e* to *f* in Fig. 5, is slightly less than 4 inches, and that of *c*, from *e* to *g*, exactly 4 inches.

Fig. 6 represents the under surface of Fig. 5, in which the crucial ridges seen in Fig. 4 are replaced by deep grooves. The line *e* of Fig. 4 is now represented by a fossa,  $2\frac{3}{4}$  inches below the level of a line drawn from *e* to *c'*. Fig. 6, *a*, represents six of the rootlet-scars, of their natural size, as seen at the base, *a*, of the root, Fig. 5, *d*; and 6, *b*, is a copy of a similar cluster from near Fig. 5, *x*, of the same root. These two figures show how the Stigmarian rootlets accommodated themselves to the increased growth of the root, not by any additions to their numbers, but by a molecular growth of the bark which pushed the rootlets further apart, this separation being accompanied by a corresponding increase in the diameter of each individual rootlet.

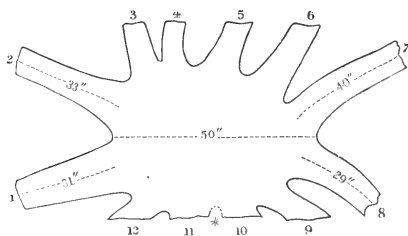
XYLOGRAPH 1.



The Xylograph 1 represents the outlines of the underside of a fine Stigmarian base of *Sigillaria reniformis* obtained by Mr. George Wild from the roof of the Bardsley Colliery, near Ashton-under-Lyne. In this specimen, which is of large size, the four primary roots become separated so near to the base of the stem that their division into four can only be made out by careful examination. Xylograph 2 is an outline of another specimen from the roof of a coal-mine at Honeywell Lane, also in the neighbourhood of Mr. Wild's colliery. I

am indebted to Mr. J. Hampden Barker for this sketch and for the careful measurements which accompanied it. The greatest diameter of the specimen was rather

XYLOGRAPH 2.



more than 9 feet from the tip of root 1 to that of root 7. The shorter roots on each side of this longer axis could not be traced, since they plunged deep into the side walls of the mine. Whilst this specimen *appears* to subdivide into twelve roots<sup>1</sup> the division into four primaries is even less obvious than in Xylograph 1. Though Mr. Binney's crucial line frequently exists, it is not a constant feature of these matured roots.

The above facts show that considerable differences exist in the length attained by these primary roots before they subdivide into secondary ones; whilst the Duckinfield tree demonstrates that their ultimate branches may extend to great lengths with but little variation in their diameter.<sup>2</sup>

<sup>1</sup> The division between the roots 10 and 11 is not very distinct, but the otherwise symmetrical arrangement of the roots leaves little doubt that a division exists there.

<sup>2</sup> This fact is not unimportant since M. Renault is disposed to recognise in such elongated examples a distinct class of organs from those which dichotomise near the base of the stem. He says, "Cette observation est difficilement explicable par l'existence des simples racines," 'Cours de Botanique fossile,' première année, p. 154. At p. 9 of his 'Étude sur les Stigmaria, rhizomes et racines de Sigillaires,' he says, 'L'épaisseur considérable que conservent les racines principales jusqu'à leurs dernières sous-divisions, la grande régularité de la ramification, le mode de disposition et la désarticulation des organes appendiculaires donnent aux *Stigmaria* un caractère tout particulier que ne se rencontre dans le système racinaire d'aucun autre type végétal, et l'on se demande si ces curieuses fossiles ne représenteraient pas plutôt des rhizomes que des racines. Dans ce cas, les organes pris pour de radicelles et auxquels Goeppert attribue le nom de *fibrilles*, ne seraient autre chose que des feuilles souterraines représentant les feuilles rudimentaires appelées *écailles* des rhizomes ordinaires.'

I shall have to show on a later page that none of these statements are applicable to *Stigmaria ficoïdes*. Subterranean rhizomes amongst the living Lycopodiaceæ differ very little in structure from the stems of which they are mere extensions. This is shown by the example of *Psilotum triquetrum*. But *Stigmaria* differs wholly both from *Lepidodendron* and from *Sigillaria* in wanting the inner vascular zone seen in both these genera, the *étui médullaire* of Brongniart, from which alone all the vascular

Having thus glanced at some of the general aspects of *Stigmaria ficoides*, we may now examine the morphology and histology of its several parts.

### THE MEDULLA.

This was an exclusively parenchymatous tissue; and, since I found it to be hollow in every one of the innumerable specimens that passed under my eye, I long ago arrived at the conclusion that *Stigmaria* possessed a fistular medulla. Owing

*bundles going to the leaves originate.* In the second place, what can be more regular than the dichotomy of the rootlets of the living Lycopods. I shall further show on a later page that the rootlets of *Stigmaria*, the "feuilles rudimentaires" of M. Renault, did not disarticulate like leaves, or leave a true leaf-scar. They have a distinctive internal organisation common to the entire series, respecting which M. van Tieghem, our highest authority on the structure of roots, says, "Par la structure du cylindre central, et par la division dichotomique qu'on y observe en plusieurs endroits, vos racines appartiennent bien certainement à un Lycopodiace de la famille des Selaginellées" ('Organisation of the Fossil Plants of the Coal-Measures,' Memoir II, p. 294). That *Stigmaria* does exhibit some characteristic peculiarities, is unquestionable, but they are very different from those enumerated by M. Renault.

Since writing the foregoing pages, I have ascertained, to my surprise, that even some of my German friends hesitate to accept the testimony of Binney, Dawson, and others on these important fundamental facts, and call for additional evidence that they are facts. This demand is easily met. A few definite points are unquestionably proven.

I. The gigantic Sigillarian stems must have had large roots. The specimens figured on my Plate I demonstrate not only that they had such roots, but that these roots branched dichotomously.

II. It is a characteristic feature of these roots that we invariably find them separating at the base of the aerial stem into four primary ones, as represented on Plate II.

III. The specimen figured on Plate III demonstrates that, when obtained in a sufficiently young state, these four roots were Stigmarian, bearing the characteristic rootlets of *Stigmaria ficoides* up to the base of the aerial stem which they sustained.

IV. The well-known Duckinfield example, now preserved in the museum of the Owens College, presents four such primary roots, which dichotomise as in my Figs. 1 and 2, and though these display no traces of Stigmarian structure in their thicker portions close to the central aerial stems, their prolonged branches are absolutely Stigmarian.

V. The absence of Stigmarian rootlet-scars from the proximal portions of the Duckinfield specimen is manifestly due to growth. The enlargement of each root having led to the decortication of the superficial cortical zone of which the exterior of the base of each rootlet was but an extension, the result was the reduction of the thick, proximal end of each root to the condition of those of Figs. 1 and 2.

We have here a few fundamental facts that it is absolutely impossible to dispute. They establish the truth that the *Stigmaria ficoides* is a root of these large trees; scientific evidence is rendered worthless if plain observations like these, made by a number of experienced observers, is to be lightly rejected. But I may add, from my own recent personal observations, that the conclusions arrived at from the above five propositions were amply sustained by observations which I made in the fine Carboniferous forest recently exposed at Oldham, where I found both Sigillarian and Lepidodendroid stems furnished with Stigmarian roots.

to the delicate structure of its cells this tissue was frequently destroyed; the area which normally represents its position being often entirely empty. But I have obtained numerous examples in which this medulla is preserved as a very thin layer, lining the vascular cylinder, as represented at Plate IV, fig. 7, *a*. The medullary character of this layer is demonstrated by the way in which extensions of it consti-

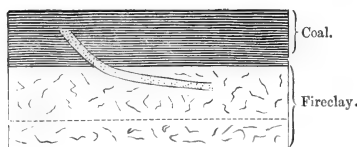
Another point respecting which some friends entertain doubt refers to the possibility of the secondary roots of large trees, whose trunks and primary roots stand upon the coal, ever being sent into and through the coal so as to reach the subjacent fireclay. The fact that these *large* roots are so constantly cut off by the coal is in itself significant. We know that such roots attained to a length of as much as fifteen and twenty feet, yet those referred to are abruptly truncated by the coal-seam at not more than three or four proximal feet of their length. What has become of the remainder of each such a root if it has not entered the vegetable soil now converted into coal? The original description of the Dixon Fold trees (Plate I) was written by John Eddowes Bowman, F.G.S. and F.L.S., whom I knew long and well as an experienced and accomplished geologist, trustworthy in the highest degree. He says of these trees, "The material on which they stand is a thin bed of pure bright coal eight or nine inches thick. It has already been said that the roots do not penetrate the coal, but are abruptly cut off at its surface, and that the immersed portions have probably been acted upon by the chemical changes going on in the surrounding vegetable mass so as not to be distinguishable from it ("On the Fossil Trees lately discovered on the line of the Bolton Railway near Manchester," 'Transactions of the Manchester Geological Society,' vol i). Having been personally familiar with these trees at the time of their discovery, I can vouch for the correctness of my old friend's description. The Duckinfield tree, also referred to above, affords a still more striking example. The truncated stump of the aerial stem was found with the bed of coal, two feet six inches thick, resting upon its broken, upper extremity. Not one of the long roots, now in the Museum of the Owens College, went deeper into the fireclay than three feet. Hence the stump, when a living tree, must have ascended high above the upper surface of the vegetable soil now represented by the coal-seam. It would be easy to multiply examples of a similar kind, found both here and in the North American coalfields. Not unfrequently such trees are met with apart from coal-seams. The St. Helen's tree was in this position, and many of the trees in the Oldham Forest were similarly circumstanced. Some of these were very young ones, and may not have lived long enough in the positions occupied by them to accumulate, over their roots, sufficient vegetable soil to form a bed of coal; or such as was accumulated may have been washed away again before sedimentary sand and mud took its place. That such local denudations have occurred is well known. In a Memoir read to the Manchester Geological Society, on the 2nd of February last, Mr. Wild, speaking of a coal to which he has recently sunk, says, "In the seat of this mine, which is a brown stone, *Stigmaria* are both abundant and good, and both roots and rootlets pass through four different layers of rock and shale to the depth of six feet below the coal. At about ten yards below the coal (New Mine) is found a coally-looking floor or parting, overlain by dark shale containing very well-formed septaria, whilst under the parting is a well-developed coal-seat or warrant (certainly a misnomer in this case), four to five feet in thickness, the *Stigmaria* in which are exceedingly good. Such cases of an under-clay crowded with once vigorous roots and rootlets capable of supporting gigantic trunks with foliage and fruit, being almost entirely robbed of the vegetation it had succoured by that relentless disturber, denudation, are by no means rare." Familiar with the pit to which Mr. Wild refers, and having collected some of the magnificent *Stigmaria* of which he speaks, I can confirm his statements respecting these seat-beds and their vegetable contents.

But I am further asked by one of my doubting friends, has anyone ever found a *Stigmarian* root or *Sigillarian* stem passing through the coal into the fireclay below? To this I answer yes. I am

tute the primary medullary rays (fig. 7, *b' b'*). Vegetable fragments which do not belong to the individual Stigmarian root, especially the ubiquitous rootlets of other individual Stigmariæ, frequently found their way into the fistular cavity. Several writers have seen the vascular bundles of these rootlets within the medullary cavities and have mistaken them for elements belonging to the root within which they observed them. In other words, they supposed that Stigmaria had not only a solid medulla, but that vascular bundles ran longitudinally through the centre of that

again indebted to my experienced and accurate friend Mr. Wild for a good example represented in the accompanying diagram. (Xylograph 3.)

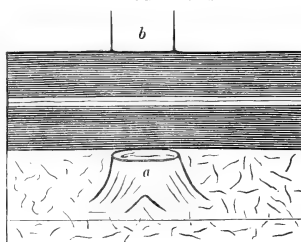
XYLOGRAPH 3.



This example is from the Dandy bed of coal, nearly fifty yards above the Arley Mine, at Tullodge, near Burnley. The specimen was a good Stigmarian root which was traced from near the roof of the coal (the latter being about two feet in thickness), through which it gradually descended, and entered the fireclay seat below. About four feet of the root was in the coal and nearly nine feet in the seat. The root in this case had been preserved from destruction by the agencies referred to by Mr. Bowman, quoted on a previous page, viz. by the fact that its cast had been filled at an early period with sandstone derived from patches of similar sandy material found in the roof of the coal.

The next diagram represents a state of things met with in November last in Mr. Wild's colliery at Bardsley known as the Pomfret Mine.

XYLOGRAPH 4.

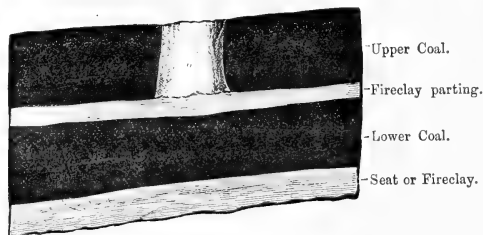


In this instance *a* is a Stigmarian "stool" embedded in the fireclay. Immediately above it, in the roof of the mine, was a "pot-hole," *b*, *i.e.* a hole from which part of an aerial stem was extracted and which there can be no doubt was the stem of the roots *a*.

Xylograph 5 represents another instance just discovered at the Bardsley Colliery, where there are two seams of coal separated by a thin parting of clay. Mr. Wild found a large stem ascending

medulla and were the sources whence the vascular bundles going to the rootlets were derived. This, however, is altogether a mistake.<sup>1</sup>

XYLOGRAPH 5.



from the clay parting, through the upper coal, and protruding somewhat into the roof of the mine. On removing this stem, the impression left by its base on the subjacent fireclay, exhibited, very clearly, the crucial marking of Plate II, fig. 4. The fireclay separating the two coals was therefore the soil in which this stem had commenced its growth and into which its roots had penetrated. In like manner, Mr. Bradbury has obtained in the Bent Mine, a stem which was bared eighteen inches below, and which not only ascended some distance into the coal but reappeared immediately above it. A record kept, for but a few months, of all the cases of stems penetrating, or continuous through, the coal would supply a sufficient number of them to make any doubt as to the possibility of such occurrences most unreasonable. At the same time it is easy to understand why such should not be the ordinary positions in which such stems and roots would be preserved. Xylograph 5 certainly represents an instance of a tree which began to grow when the lower coal was covered by a layer of fireclay, in which latter it took root, and which continued to grow sufficiently long to allow the base of its stem to be imbedded in the vegetable soil ultimately converted into the upper coal. In the same way, if the stem *b* of Xylograph 4 really belonged to the base, a still more remarkable survival of the tree-trunk must have taken place. But the length of the life of the stem necessary, in all probability, for the accumulation of sufficient vegetable soil to form a thick bed of coal would be so great as materially to exceed the duration of any tree—living or dead. Hence it is that we so frequently find these rooted stems resting upon the coal, into which, however, their Stigmarian roots freely plunged.

Having so many proofs that some of the examples of *Stigmariæ* discovered in the fireclay or seat-bed are the downward extensions of *Sigillarian* and *Lepidodendroid* trees, it surely can no longer be doubted that the fragments of this identical *Stigmaria ficoïdes* with which that clay is so constantly filled must also be portions of similar roots. Such fragments, both of roots and rootlets, are extremely abundant. Indeed, it is rare to find a fireclay in which such is not the case; but how these roots have so often become disturbed and broken up is a question not easily answered.

<sup>1</sup> In p. 214 of my Memoir II, 'Phil. Trans.,' 1872, referring to a retrogressive tendency on the part of several writers on *Stigmaria*, I said "the first movement in the wrong direction originated with Professor Goeppert, who described a *Stigmaria* ('Genres des Plantes Fossiles,' tab. 13) with vascular bundles passing longitudinally through the pith, and from which he believed the vascular bundles going to the rootlets were supplied. In this he was followed by Sir Joseph Hooker ('Memoirs of the Geological Survey of Great Britain'), who clearly affirmed the existence of medullary rays and bundles, but adopted Goeppert's idea as to their origin." "Mr. Binney recognised



That the bundles which Goeppert and Binney found in the interior of these Stigmariæ were those of Stigmarian rootlets is undoubted, but those rootlets had no individual relationship to the plants in which the two authors found them. They were such as had intruded themselves into the medullary cavity from without, just as they have entered into nearly every fragment of a plant from the Oldham and Halifax deposits, whence most of our rich stores of specimens have been derived. Permeating both the vegetable soil, now converted into coal, and the seat clay, in the most extraordinary profusion, the smallest opening in any part of a vegetable fragment was penetrated by these rootlets, making the study of such specimens extremely perplexing to palæontologists whose eyes are not familiar with the aspects assumed by these erratic rootlets. Plate VII, fig. 14, *g*, presents an instance of a rootlet, with its central vascular bundle, *f''*, in the medullary cavity of a Stigmarian vascular cylinder. In Plate X, fig. 42, we have a large rootlet, *g*, into the interior of which several younger, but otherwise similar, rootlets have penetrated. My cabinet contains another example in which a small rootlet has penetrated a somewhat larger one, and these two, in turn, have entered together into a third of yet larger dimensions. Mr. Binney unfortunately adhered to his error even in his latest writings.

#### THE VASCULAR OR XYLEM CYLINDER.

The transversely barred tubes composing this cylinder belong to the type designated by Brongniart *Vaisseaux rayées*. They are either vessels or Tracheids (Plate VI, fig. 9, *b*; Plate VII, figs. 10, *b*, and 11, *b*), assuming the latter form especially where lateral bundles are given off.

At the earliest appearance of this cylinder in a young root the vessels occupying the position, though not fulfilling the functions, of the protozylem of an exogenous stem, constituted a thin ring of very small vascular bundles surrounding a medulla. These bundles, the vessels of each of which retained their mutual parallelism, did not themselves pursue a straight, longitudinal, but an undulating, course through the stem, as at Plate V, fig. 8, the undulating curves of one bundle being opposed to those of its neighbour on either side. The result of these wavy undulations was that contiguous bundles alternately touched and separated from one another, enclosing, in the latter case, large, vertically elongated, lenticular spaces (fig. 8, *b'*), occupied by extensions of the medullary parenchyma which thus reached the bark. As the vascular cylinder grew exogenously each new, superadded vessel followed

the medullary rays, but, as already mentioned, again adopts Goeppert's explanation of the origin of the vascular rootlet bundles."

exactly the undulating course of those upon which it rested. The result was that these lenticular spaces became widened, without interruption, into what I have elsewhere designated primary medullary rays; and which thus continued to receive peripheral additions to their length so long as the vascular cylinder continued to increase in diameter (Plate VI, fig. 9, *b'*).

When tangential sections are made of any portion of the vascular cylinder, these medullary rays are intersected transversely, and always present, in such sections, a vertically elongated lenticular outline (Plate V, figs. 8, *b'*, and 16, *b*). On making two such sections of the same ray, one near the cortex and another close to the medulla, as in Plate IX, fig. 12, and Plate V, fig. 13, the former being the medullary and the latter the cortical section, it will be seen that the size of the latter greatly exceeds that of the former. In other words, these rays, which in my 'Memoir,' Part II ('Phil. Trans.'), I have designated *primary* medullary rays, increase in size as they proceed from within outwards.

The same result is seen in transverse sections of the vascular cylinder (Plate VII, fig. 14, *b' b'*). These rays were normally filled with an outward extension of the delicate medullary parenchyma, but this tissue has often failed to be preserved. In the section, Plate IV, fig. 7, *b' b'*, we find the cells of this tissue elongated in the direction of the ray, but in such sections as are made at right angles to the long axis of each ray, as in Plate V, fig. 16, *b*, the tissue resembles a delicate small-celled parenchyma. Vascular bundles derived from the xylem cylinder (Plate V, fig. 16, *f*), to be referred to again more fully, are deflected outwards through these rays on their way to the rootlets.

A transverse section of an entire vascular cylinder (Plate VII, fig. 14, and Plate VIII, fig. 15, *b*) exhibits its component vessels grouped in wedge-shaped segments of unequal sizes. This segmentation is almost wholly due to the intervention of the primary medullary rays. The variable diameters of the wedges depend upon whether the section has crossed individual rays at their broader part, or at their narrower superior or inferior extremities, where they contract to the dimensions of the ordinary, inconspicuous medullary rays. As already stated, the cellular tissue, extended from the medullary parenchyma to fill the primary rays, appears in such sections as Plate V, figs. 13 and 16, as if it also was parenchymatous, but in sections like Plate IV, fig. 7, *b'* it assumes a prosenchymatous form. In vertical radial sections it exhibits a more mural aspect.<sup>1</sup>

Besides these large "primary" medullary rays the vertical laminæ of the vascular cylinder are separated by numerous smaller "secondary" rays (Plate IV, fig. 7, *b''*, and fig. 20, *b'', b'''*). In radial longitudinal sections (Plate VI, fig. 9, *b''' b'''*) these secondary rays are arranged in unequal groups often composed of several superimposed rows of cells. In transverse sections of the cylinder they are un-

<sup>1</sup> See 'Memoir,' Part II, Plate xxx, fig. 43, *ff* ('Phil. Trans.').

equally conspicuous. In tangential sections they are readily discerned (Plate VII, fig. 11,  $b''b''$ ), sometimes limited to a single cell, at others consisting of several such cells. In the majority of cases these rays consist solely of radially elongated parenchyma, but they sometimes contain small barred Tracheids, as in  $b''$ , Plate IV, fig. 17. I can obtain no explanation of the significance of this substitution beyond what follows.

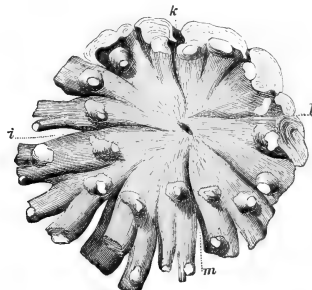
In 'Memoirs,' Part II, p. 236, Plate xxvii, fig. 23, and in Part XI, p. 294, Plate liii, fig. 21, and Plate liv, fig. 22 ('Phil. Trans.'), I showed that similar barred Tracheids enter into the composition of the ordinary medullary rays of some species of *Lepidodendron*, and that Corda found them in his *Diploxyton cycadeoideum*. It is probable, therefore, that the presence of these barred Tracheids in the medullary rays may characterise some species of *Lepidodendra* and *Sigillariæ*, whilst they are absent from others; and since the vascular zone of *Stigmaria* is a mere downward extension of the exogenous zone existing in the aerial stems of the above plants, similar differences may be expected to exist in the roots of the same species.

That this vascular cylinder grows exogenously by means of a meristem ring, equivalent to a cambium-zone, is no longer disputed. The specimens in my cabinet demonstrate this fact. My largest cylinder is one from the Staffordshire coalfield, for which I am indebted to Mr. Ward, of Longton, the possessor of the well-known collection of the fossil Carboniferous Fishes of Staffordshire. Its mean diameter is about  $1\frac{3}{16}$  ( $= 1.186$ ) of an inch. On the other hand, I have a perfect vascular cylinder from Halifax, the diameter of which is only  $\frac{5}{16}$  ( $= .412$ ) of an inch (Plate V, fig. 16, A). A third, equally perfect, is  $\frac{3}{16}$  ( $= .187$ ) of an inch in diameter; yet smaller than either of these must have been one belonging to the section of the bark and rootlets represented in Plate IX, fig. 18. The two outer cortical layers being well preserved in this section we can ascertain the original mean diameter of the entire root, which has been about  $\frac{3}{16}$  ( $= .218$ ). In its centre,  $b$ , but in a disarranged state, are the vascular wedges that constituted the xylem cylinder, and which in all probability did not exceed, if it even reached, .1 of an inch in diameter.<sup>1</sup> *Stigmarian* roots which I examined in the Oldham Forest, attached to the aerial stems, tapered away to very small dimensions.

<sup>1</sup> Specimens of *Stigmaria* are occasionally met with which contract suddenly from a diameter of three or four inches to an obtuse point. Such examples have been quoted to show that all the roots of *Stigmaria* terminated in this abrupt manner. Thus, in his general outline of the characteristics of *Stigmaria*, M. Renault says: "Son extrémité était obtuse et légèrement aplatie" ('Cours de Botanique fossile,' première année, p. 152, 1881). In the course of a prolonged life I have only met with one fragmentary example of this kind. Steinhaur says ('Trans. American Phil. Society,' vol. i, 1868): "Amongst the vast number of specimens examined, only one was detected which appeared to terminate, closing from a thickness of three inches to an obtuse point." Whilst recognising that these, with some other peculiar forms, "were only monstrosities," the same author tells us that he

The rarity of small branching specimens, along with other facts, seems to show that after the first two consecutive bifurcations occurred within a limited distance from the central stem, no others took place in the true roots. The long, had seen no examples of Stigmarian roots less than two inches in diameter. Like Mr. Steinbaur, I am convinced that such examples of Stigmarian roots, terminating like thick cucumbers, were abnormal, although my friend Sir William Dawson tells me that in Canada he has found ordinary roots terminating in this obtuse form more frequently than we do in Great Britain. In all probability some accidental cause had arrested the further longitudinal growth of such roots, though they continued to swell transversely. Unquestionably the specimens described above, along with others in my cabinet, demonstrate that these roots ultimately tapered away to extremely small twigs. Proof of this was abundantly furnished by the trees in the Oldham Forest, already referred to. It is possible that some of the obtuse specimens spoken of above are fragments of examples like one described and figured by Mr. Richard Brown, of which figure the accompanying Xylograph 6 is a copy. This memoir is entitled "Description of Erect Sigillariæ with Conical

XYLOGRAPH 6.



Tap-roots, found in the Roof of the Sydney Main Coal in the Island of Cape Breton" ('Quarterly Journal of the Geol. Soc. of London,' vol. v, p. 354). The specimen figured is the under surface of the base of a stem, in which the four primary roots divided and subdivided so rapidly that thirty-two roots were seen within a circle of eighteen inches in diameter. "Besides this," the author says, "there are four large tap-roots in each quarter of the stump, as shown in fig. 7, and about five inches beyond these a set of smaller tap-roots, striking perpendicularly downwards from the horizontal roots, making forty-eight in all, viz. sixteen in the inner and thirty-two in the outer set." Page 358, "The inner set of tap-roots vary from two to two and half inches in length, the diameter at their junction with the base of the trunk being about two inches." "The outer set are much smaller, being about one inch in diameter at their junction with the horizontal roots, and from one to one and a half in length. A thick tuft of broad, flattened rootlets radiates from the terminations of the tap-roots and a few indistinct areolæ are visible on their sides."

Remembering that in many recent Lycopods the roots branch alternately in vertical and horizontal planes, the above description suggests that some Stigmarian roots have attempted to do the same thing, though more or less abortively, owing possibly to unfavorable conditions preventing them from penetrating the soil. At any rate, we learn from Mr. Brown's description that such undeveloped roots were capable of being produced exceptionally, which fact renders probable my explanation of the obtuse forms to which this note refers. It is possible, however, that the above plant may have been a form distinct from our common type. If the letters *i*, *k*, *l*, and *m*, represent the subdivisions between the

terminal undivided roots, thus formed, may be identical with what led M. Renault to doubt their being roots and to regard them as rhizomes.

#### EXOGENOUS GROWTH OF THE VASCULAR CYLINDER.

As already observed, the existence of this growth, alike in the aerial stems of *Sigillariæ*, of most *Lepidodendra*, and in their common *Stigmarian* roots, is no longer disputed. The great differences in the diameters of their several vascular cylinders can be accounted for in no other way. But independently of the argument derived from the necessities of the case, our specimens demonstrate its occurrence. Thus in the section Plate VII, fig. 14, we find at *b'' b''* a thin peripheral zone of vascular laminæ, sharply distinguished from those which it encloses, by the much smaller size and less regular distribution of its component vessels. A portion of this peripheral zone, enlarged 39 diameters, is shown in Plate IV, fig. 19. At *b* we have the outer margin of the matured wedges of the older portions of the cylinder, whilst at *b'* is the layer of new growths. Though the vessels of the latter are of smaller, though unequal, sizes, they are obviously prolongations of the older laminæ. They correspond, in these respects, with similar young growths occurring in various other Carboniferous plants in which this exogenous development occurs.

The existence of such a process of exogenous growth demands the pre-existence of some meristemic equivalent of a cambium. Plate IV, fig. 20, represents such a layer. Like fig. 19, this is part of a transverse section of a vascular cylinder, enlarged 75 diameters, the outermost vessels of which are seen at *b* separated by the secondary medullary rays, *b''*. At *c* we have a thin investing zone of what, in this section, appears to be an extremely delicate but otherwise ordinary form of parenchyma, the cells of which tend more or less to arrange themselves in radial rows with parallel tangential divisions. Plate VII, fig. 10, is a radial, longitudinal section through the same specimen as fig. 20, in which *b* again represents the outermost vessels of the xylem cylinder. But we now see that the layer *c* of fig. 20 consists of narrow, vertically elongated cells with square ends, and which may fairly be regarded as cambiform products of a cambial layer, the meristemic activity of which may have manifested itself irregularly rather than periodically. The elements composing this cambiform layer being so very different from any which enter into the composition of the true cortex, we can scarcely doubt that their function has been as specialised as their structure and position, and that they represent the zone within which the exogenous growths, successively added to the exterior of the vascular cylinder, originated.

four primary roots, each of these has subdivided much more frequently, apart from the so-called Tap-roots, than is the case with our ordinary examples of *Stigmaria ficoides*.

Hitherto I have failed to discover any specimen showing the exact relations of the exterior of this cambiform zone to the innermost one of the true cortex; hence I am unable to say whether or not the former adds in any way to the growth of the latter, or, in other words, whether any proper phloem zone exists in a Stigmarian bark. The probability that something of the kind will be found is suggested by the fact that we appear to have a true phloem element in the vascular bundles of the rootlets, as will be shown on a later page. In Plate VII, fig. 10, we discover at *dd* some groups of what appear to be irregular cells intermingled with the cambiform cells, and which appear to be inward extensions of a more external parenchymatous layer, the exact nature and relations of which I do not yet fully understand.

#### THE CORTEX.

This structure, so far as I understand it, consists of three zones, which pass more or less gradually into one another. In the cortex of my youngest specimen (Plate IX, fig. 18) only two zones are seen, *d* and *d'*, as shown in Plate X, fig. 21, enlarged 18 diameters. The outermost of these, *d*, is parenchymatous, and the cells are without any special arrangement; in the inner zone, *d'*, the cells are arranged in radial parallel lines; the transition from the one to the other being rather abrupt. The thickness of the combined layers is about  $\frac{1}{20}$  ( $= \cdot 05$ ) of an inch, that of the inner one, *b*, being about  $\frac{1}{40}$  to  $\frac{1}{50}$  of an inch.

Having no longitudinal section of the above specimen, we learn from it nothing of the relations of the two layers. But when we turn to roots of larger dimensions and older growth, such sections throw some light upon the matter, though their structure is more complicated. The outermost cortical layer (Plate VIII, fig. 15, *d*, and Plate VI, fig. 9, *d*) is always, as in the above-mentioned fig. 21, a simple parenchyma. But, though the lengths and breadths of the cells are about equal in all directions, the thickness of the layer as a whole varies in different specimens. The sizes of the cells vary in the same specimen, and still more in different specimens, the latter differences being due to age.

In the very young example, Plate X, fig. 21, the cells average from  $\frac{1}{400}$  ( $\cdot 0025$ ) to  $\frac{1}{800}$  ( $\cdot 00125$ ), the mean thickness of this layer of parenchyma being about  $\frac{1}{80}$  ( $\cdot 016$ ) of an inch. In the older specimen represented in Plate VI, fig. 9, the corresponding layer has a maximum thickness of about  $\frac{1}{10}$  ( $\cdot 1$ ) of an inch, and its cells vary from  $\frac{1}{150}$  ( $\cdot 006$ ) to  $\frac{1}{300}$  ( $\cdot 003$ ) in diameter. Hence, whilst the outermost bark in the order of these two specimens, as contrasted with the younger one, has increased in breadth six times, its component cells have less than three times the diameter of the younger ones. Such being the case these cells must have more than doubled

their number. We thus learn that cell-growth in these primæval trees seems to have obeyed the same laws as regulate that growth in plants now living.<sup>1</sup>

The second layer of the outermost Stigmarian bark is one of some interest, both morphologically and physiologically. In my 'Memoir,' Part IX, p. 353, I called attention to the occurrence, in the Oldham calcareous nodules, of fragments of a singular form of bark, which I referred to Sigillaria and Stigmaria. I have now no doubt respecting the accuracy of this reference, and that the bark is identical with that now under our notice.

To understand its true nature we must examine this tissue alike in transverse, radial, and tangential sections. Plate X, fig. 21, represents, as already observed, a small portion of the outer bark of the very young specimen, Plate IX, fig. 18, enlarged 18 diameters; in this figure the layer now under consideration (fig. 21, *d'*) appears as a series of cells, differing little from those of the investing parenchyma, *d*, except in their more uniform size, and their regular arrangement in parallel, radial rows.

In Plate VIII, fig. 22, we have a transverse section of the corresponding portion of the specimen Plate VIII, fig. 15, also enlarged 18 diameters. In this section the layer *d* retains its parenchymatous form, but *d'*, whilst still consisting of radial lines of cells separated by tangential septæ, not only has those septæ of very unequal lengths, but each radial group is circumscribed by a strongly-marked boundary line, *d''*, separating it from the contiguous parallel groups. In Plate VIII, fig. 23, we have a similar section to fig. 22, also enlarged 18 diameters, but taken from a yet older root. We now find the layer *d'* of the preceding section has become more complicated. The rows of tangentially divided cells have lengthened radially, and though tangential divisions still predominate, even at the more external part of the layer *d'*, we now find some radial divisions introduced amongst the tangential septa of many of the groups. In addition, many of the innermost cells of the parenchyma, *d*, contiguous to the outer ends of these groups, exhibit a peculiarly disturbed arrangement that does not appear in fig. 22.

In Plate VI, figs. 9, *d'*, and 45, *d'*, we again see the layer just described, but now in radial vertical sections. The groups of cells are again disposed radially, only the parallel tangential septa are now elongated vertically, instead of tangentially as in transverse sections. The radial boundary lines *d''* of fig. 23 are again seen in *d''* of this and similar sections. In my 'Memoir' (IX, pp. 354, 355) I described the cells thus separated from one another by tangential septa as "tabular cells

<sup>1</sup> "An increase in the average breadth of the individual cell no doubt takes place, judging from estimates. It appears to rise rapidly to an approximately constant value, and then to maintain this during succeeding divisions, so that cells of the same layer in a stem a foot thick are no broader than in one as thick as one's finger, though they are of course more numerous in a corresponding degree. The final, constant average dimensions are relatively little in excess of those existing originally at the beginning of the growth in thickness; they may amount to scarcely more than two or three times the latter." (De Bary, 'Comparative Anatomy of Phanerogams and Ferns,' English translation, p. 538.)

whose broad parallel sides are parallel to the surface of the bark, whilst their shorter axes are radial. In a word, the cells stand upon their thin bevelled edges, with their two flat parallel surfaces severally directed towards the medulla and the periphery of the bark." So far this description remains applicable to the corresponding cells of *Stigmaria*.

We learn something further respecting these curious cells from tangential sections of them. We have such a section in Plate VIII, fig. 24. We now find that the dark boundary lines,  $d''$ , of Plate VIII, figs. 22 and 23, reappear as the strongly marked walls of mother-cells, 24,  $d''$ , whose vertical lengths rather exceed that of their transverse ones, which explains the greater length of the parallel tangential septa in the vertical section, Plate VI, fig. 9,  $d'$ , as contrasted with their shorter lengths in figs. 22 and 23. But the tangential section further shows that nearly every one of these tabular cells is undergoing secondary subdivisions (fig. 24,  $d''$ , see also Pl. V, fig. 49). Most of these secondary septa are horizontal and parallel with one another, though occasionally a few vertical septa may also be noted.

I have dwelt with what may appear to be unnecessary minuteness upon the structure of this cortical zone, but the results of these detailed studies are not unimportant physiologically. We are dealing with anomalous primæval morphologies, and it is desirable to learn, so far as we can, the physiological truths which these morphologies seem to reveal. The facts stated above demonstrate that in the layer  $d'$  we have a peculiar meristem tissue or bark cambium of remarkable activity, producing vertical cell divisions, seen in transverse and radial sections, as well as horizontal divisions seen in tangential sections. Such meristemic action is obviously designed to make additions to the cortical structures. The next question requiring an answer is what part of the bark benefits by this meristemic activity?

One portion of this question is easily answered. Internal to the zone  $d$  we have in all the more matured specimens a prosenchymatous zone,  $e$ , which, though of very limited thickness in the younger roots, becomes the chief constituent of the bark in older roots. In all the transverse sections the cells of this zone are arranged in straight, radial, parallel lines, the individual cells becoming gradually smaller and more prosenchymatous as they approach the interior of the root.<sup>1</sup> In Plate VIII, fig. 22,  $e$ , they have a diameter of about  $\frac{1}{1200}$  (.00083) of an inch. At fig. 23,  $e$ , of the same plate, their diameter is about  $\frac{1}{800}$  (.00125) to  $\frac{1}{1200}$  (.00083).

Plate IV, fig. 25, represents a transverse section, enlarged 3 diameters, of a specimen of *Stigmaria* where this prosenchymatous zone,  $e$ , approaches near to the wedges of the vascular cylinder,  $b$ ; and Plate VII, fig. 26, represents a portion of the same zone further enlarged to 18 diameters. The thickness of the prosenchymatous layer in the original of these figures, now about .65, must once have

<sup>1</sup> Tangential sections of these cells are seen in Pl. VIII, fig. 24, A.



been much greater, since the specimen has evidently been much compressed; the dark disorganised bands, *e'* (fig. 26), having normally been composed of the same tissues as the intermediate bands, *e*, in which the radial lines of cells are less disturbed.

The preceding facts make it evident that the prosenchymatous zone *e* has originated in the centrifugal meristemic action of the zone *d'*, a conclusion which agrees with my previous determination as to the centrifugal development of a similar prosenchyma in the stems of *Sigillaria* and *Lepidodendron*.<sup>1</sup>

But a second physiological question is less easily answered. We have already seen that growth is accompanied, not only by a general increase in size and by a dilatation of the individual cells of the outer zone, *d*, of the bark, but by a considerable increase in their number. Whence have these new cells been derived? I have never observed any signs of meristemic action amongst the cells actually composing this layer, yet they must have been multiplied somewhere by such action. I am therefore disposed to conclude that the meristem zone, *d'*, of Plate VIII, fig. 23, has added centripetally to the outer parenchyma, *d*. If so, the true position of the bark-cambium must have been somewhere about the centre of the zone *d'*, where the tangential septa were most closely approximated, and where the secondary horizontal fissions, seen in the tangential section (Plate VIII, fig. 24), were being most actively produced. This view, if correct, explains the disturbed arrangement at the inner part of the zone *d* in fig. 23, where the parenchymatous cells were being liberated from the more internal radial lines in which they had undergone their meristemic development, but had not yet assumed the characteristic form seen in the layer *d* of fig. 22.

We have thus strong reasons for concluding that, in addition to a true cambial layer which produced fresh zones of xylem, these Carboniferous Cryptogams also possessed a bark-cambium which acted both centrifugally and centripetally, like the phellogen of recent Exogens, only instead of producing true phellem externally and phelloderm internally, this active zone produced parenchyma externally and prosenchyma internally. What has already been described, however, shows that the meristemic energy must chiefly have been expended on its inner side, since the prosenchymatous layer evidently constituted by far the largest element of the Stigmarian bark.

In no case does this latter layer seem to have become a periderm. It is always, in the specimens which I have obtained, enclosed within and protected by the parenchymatous zone, *d*, of which the rootlets are partly an extension, and upon which they are planted. Hence we may be assured that so long even as the mere bases of these rootlets remained intact, the parenchymatous periderm remained equally so. That such must have continued to be the case so long as the increase

<sup>1</sup> See 'Memoir,' Part II, pp. 285, 286.

in the size of the roots continued to progress is obvious, since it is clear that if the superficial layers of the bark had been successively thrown off until the parenchyma wholly disappeared, the meristem zone,  $d'$ , must have been the next to perish, which would apparently have arrested all further growth in the thickness of the bark; a result the occurrence of which does not seem to have taken place so long as the trees continued to live. That the more superficial portions of the parenchyma were so cast off is suggested by the gradual disappearance of the rootlet-scars so conspicuous in Plate III, figs. 5 and 6, but which are either entirely wanting, as in Plate I, figs. 1, 2, and Plate II, fig. 3, or very feebly represented in the extremities of Plate II, fig. 4, and Xylograph 1.

#### THE ROOTLETS AND ROOTLET BUNDLES.

The Lower Coal-Measures of Lancashire and Yorkshire have furnished nearly all the trustworthy knowledge we possess respecting these organs. That knowledge, however, is now so complete that but little remains to be added to it. Some little new light was thrown upon the subject in my Memoir, Part II, Plates XXIX and XXX ('Phil. Trans.'). But since that Memoir was published much additional information has been obtained.

#### ORIENTATION OF THE ROOTLET BUNDLES.<sup>1</sup>

The longitudinal section of the zylem cylinder, Plate VI, fig. 9, illustrates this subject. All the vessels of special narrow radial laminæ of the cylinder, from their innermost to their outermost margins, are suddenly deflected outwards, as at  $f$ , to be prolonged through the cortical zone as a rootlet-bundle. When the exogenous zone of a very young root is in process of development, as in Plate VI, fig. 9, its outermost and newest formed Tracheids follow the course pursued by the older vessels on which they rest, and reappear in corresponding relative positions in transverse sections of each bundle as will be shown at page 31. As this bundle proceeds outwards through the vascular cylinder, it increases in size transversely as well as vertically. The formation of the bundle begins in the deflection of a solitary vessel, which is the innermost and youngest one of a single radiating vascular lamina, hence it is consequently a vessel of small diameter. As newer additions of larger vessels are made exogenously to the vascular cylinder, the portion of each new growth that is in the radial line of the lamina originating the bundle contributes

<sup>1</sup> M. Renault says that these bundles "prennant naissance vers l'extrémité interne des coins de bois," 'Cours de Botanique fossile,' première année, p. 156. This is true so far as the *commencement* of their formation is concerned; but, as will be shown in the text, they continue to arise from the entire radius of that vascular wedge to whatever diameter it may attain. The erroneous notions of Professor Goeppert and Mr. Binney on this question have been already dealt with at p. 12.

to the further development of that bundle. But as this outward extension of the vascular cylinder progresses, more laminae than the primary one from which the bundle originated, take part in that extension; hence, as it grows, the bundle increases in diameter as well as in depth. This synchronous development, both by the lateral and superior apposition of new vessels, explains the wedge-shaped contour which each of these bundles presents, when the deflected vessels are intersected transversely, as in the tangential sections of the vascular cylinder shown in Plate V, fig. 8, Plate IX, fig. 12, and Plate V, figs. 13, 16. In consequence of this mode of development the smaller and oldest vessels of the bundle, forming the apex of the wedge-shaped transverse section, invariably point downwards, or are acropetal when considered in their relations to the root to which the rootlets belong.

Transverse sections of the xylem cylinder, like Plate VII, fig. 14, show these bundles passing outwards as at *f* and *f'*. These sections also demonstrate the increase in the lateral diameter of the bundle as it passes outwards. The two directions of increase are well illustrated by comparing two transverse sections of the same bundle drawn to the same scale; the one, Plate IX, fig. 12, made tangentially through a vascular cylinder near its medullary surface, and the other, Plate V, fig. 13, made close to the periphery of the cylinder. The primary medullary ray, *b*, of fig. 12, like the similar one, Plate V, fig. 16, *b*, is comparatively narrow, and the rootlet bundle, *ff'*, passing through it, is also small, both in length and breadth. Plate V, fig. 13, represents a parallel section of the same ray as fig. 12, but made close to the periphery of the cylinder. Both these figures are equally enlarged 30 diameters. The increase in the magnitude alike of the primary ray, *b*, and of the rootlet bundle, *f*, in fig. 13, is conspicuous, and corresponds with what we observe in longitudinal sections of the rays and bundles as seen in transverse sections of the vascular cylinder like Plate VII, fig. 14, *ff*.

Each bundle of vessels, thus separated from the xylem cylinder to constitute a rootlet bundle, contains secondary medullary rays between its component vascular laminae, both in its vertical portions (Plate V, fig. 16, *d*), and for a short distance after they become deflected horizontally (fig. 16, *d'*). In these positions, unlike those of the cylinder itself (Plate VII, fig. 11), they often consist of two or more vertical rows of cells.

Transverse sections made of these rootlet bundles after their escape from the periphery of the vascular cylinder assume the various forms represented in Plates IV, IX, and XI, figs. 28 to 36. In this portion of their course the bundles, as seen in such sections, exhibit an irregularly triangular or wedge-shaped outline, the broad base of each wedge consisting of the latest additions to the bundle; and its narrow apex, *f'*, corresponding to the points indicated by the same symbol in figs. 12, 13, and 16. The figs. 28—34 are all taken from the periphery of one vascular cylinder, and are enlarged 80 diameters. Figs. 35 and 36, similarly

enlarged, are taken from Mr. Ward's large Staffordshire vascular cylinder, on the periphery of which similar wedge-shaped bundles are numerous.<sup>1</sup>

As we have already seen, each of these rootlet bundles originates, when the root is in its youngest state, as a single very small vessel, the dimensions of which bear a ratio to those of the young cylinders whence it emanates. In like manner, as the vessels of the newer additions to that cylinder increase in size, such portions of those additions as enter into the formation of the pre-existing rootlet bundles do the same. Yet after many such additions have been made, and the bundle has attained to relatively large dimensions, we not unfrequently find, added to its broad base, and especially to its two basal corners, a few vessels, the diameters of which are little more than those (*f*) of what may be called the protoxylem of the bundles. Such additions are seen at *f*, Plate IV, fig. 31. As already pointed out, these later additions are derived from new and half-developed zones that are being added to the exterior of the vascular cylinder, as represented in Plate IV, fig. 19, *b'*. We shall find that similar conditions, due to similar causes, reappear after these bundles have escaped from the cortex and constitute the central structures of the actual rootlets.

As to the regularity of their radial arrangement, to which M. Renault attaches so much importance, the vessels composing these bundles, whilst they are passing through the bark, exhibit a considerable variability. Plate IV, fig. 28, on the one hand, Plate IX, fig. 35, and Plate XI, fig. 36, on the other, illustrate this statement. Yet that all these figures, including their innumerable intermediate modifications, are but vegetative repetitions of the same organ, is certain.

Plate XII, fig. 37, is a fragment of a *Stigmaria*, split vertically, which has revealed the exterior of the vascular cylinder at *b*, whilst the rootlet bundles, *f*, escaping successively from that cylinder, bend downwards and outwards. This is the only specimen I have obtained which demonstrates the regularity of this arrangement.

Plate XII, fig. 38, is one end of a portion of the vascular cylinder of a specimen exactly resembling fig. 40, from Mr. Bayles' brickyard near Leeds, and for which I am indebted to Professor Green, of the Yorkshire College of Science. Primarily they and others were derived from below the Crow Coal. The medullary cavity of fig. 38 is occupied excentrically by a large intruded Stigmarian rootlet with its conspicuous vascular bundle. Fig. 39 is a lateral view of the same specimen. Both these figures are of the natural size. On the exterior of fig. 39 we see numerous rootlet bundles, *f*, escaping from the periphery of the cylinder in a regular order, disturbed only by the circumstance that, the inner cortical zones having disappeared,

<sup>1</sup> On various occasions M. Renault has affirmed that there are two distinct classes of these bundles, which he illustrates by Plate xx, figs. 1, 2, 3 of his '*Cours de Botanique fossile*,' première année. He says that whilst his wedge-shaped bundle, fig. 1, has supplied a leaf, figs. 2 and 3 are the bundles of rootlets. The absence of all foundation for this distinction will be discussed on a later page.

a ferruginous clay has occupied the vacant space and pressed the free, broken ends of the bundles into close contact with the surface of the cylinder, instead of retaining them in their normal positions. Beyond what we learn from fig. 37, none of my specimens give me any further information respecting these bundles until we again meet with them in Plate XII, fig. 41. This figure represents the inner surface of a thin portion of the outermost bark of a *Stigmaria*, the opposite surface of which displays the usual rootlet-scars. The free ends of several bundles have been left exposed by the decay of the tissues through which they had passed, and intrusive clay has acted upon them as upon those of fig. 39, though in the opposite direction. I am indebted for these interesting fragments to Mr. B. Holgate, of Leeds, from whom Professor Green obtained the specimen (Plate XII, figs. 38 and 39).

We have now to examine the free *rootlet* as an external appendage to the bark. These rootlets are long, cylindrical bodies, of nearly uniform diameter throughout their length, which radiate with vegetative regularity from the entire circumference of the root. Their length and diameter alike vary with their ages. The longest examples which I have measured have been twelve inches in length, but other observers record examples that have been fifteen. The greatest diameter attained by any of my uncompressed specimens is  $\cdot 4$  of an inch.

Plate X, fig. 42,  $g'$ , exhibits the usual appearance of their transverse sections. It is one of six small rootlets which have found their way, through some accidental opening, into the interior of the larger rootlet,  $g$ . The peripheral zone,  $g''$ , consists of parenchymatous cells, which in this instance have nearly uniform diameters, though very frequently they increase in size from without inwards. Within this cortical zone we have, with rare exceptions, the vacant space,  $g'$ ; in the specimens from our Lancashire and Yorkshire nodules this space is always occupied by the white infiltrated mineral substance, which permeates all the vegetable fragments found in the nodules, and which has contributed so materially to their exquisite preservation. The probability is that these rootlets were fistular, as is the case with the rootlets of the living *Isoetes lacustris*. I have seen no trace of tissue occupying it even in the youngest and smallest rootlets met with, except at their extreme bases where each rootlet is embedded in the exterior parenchyma of the *Stigmarian* bark. Within the zone  $g''$  is the vascular bundle  $f'$ , enclosed in a cellular cylinder which technical accuracy can scarcely allow us to call a bundle sheath, though it seems to act as one. A similar example of a transverse section of a rootlet intruded within the medullary cavity of the *Stigmarian* root is seen in Plate VII, fig. 14 ( $f''$  and  $g$ ).

But whilst the structure of sections like the two just referred to is very simple and easily understood, a more complicated organisation exists in the basal parts of these rootlets; and longitudinal sections of these basal portions enable us to understand much of their relations to the roots upon which they are planted.

Plate X, fig. 43, Plate VI, fig. 45, and Plate VIII, fig. 15, alike show that the parenchymatous layer  $g''$  and  $g$  of Plate X, fig. 42, is a cylindrical extension of the outermost parenchyma,  $d$ , of the cortex of the root. The exact sources whence some of the more internal layers of the rootlets were derived is less easily determined, owing to our not having yet succeeded in tracing any bundles, in unbroken continuity, from the point of emergence from the vascular cylinder to the periphery of the bark.

No one of the numerous sections of rootlet bundles, made, like figs. 28 to 33, Plate IV, close to the vascular cylinder whence those bundles have just issued, shows any definite indications of being enclosed in a special bundle cylinder, such as invests each one when it reaches the base of a rootlet. Yet the rounded contour of the similar bundles of fig. 39, Plate XII, suggests that they must have possessed such an investment. We recover the interrupted continuity of the bundles at Plate X, fig. 43,  $f$ , and Plate VI, fig. 45,  $f$ , at which point each bundle penetrates a specialized tissue upon which every rootlet is planted. This tissue forms a short, broad, cellular cylinder,  $h$ , which I would designate the *rootlet cushion*. It is composed of innumerable parallel rows of very small cells, arranged radially, which pass outward through the prosenchymatous zone,  $d'$ , of the bark, and extend into the interior of each rootlet, within which they terminate in a conical projection, as in Plate VIII, fig. 15,  $h$ , Plate X, fig. 44,  $h'$ , and Plate VI, fig. 45,  $h'$ . In some instances, as in Plate X, fig. 43,  $h$ , its radial lines of cells describe complex curves. In the latter figure, as also in fig. 45, we find the vascular bundle entering the base of the cushion at  $f$ . In Plate VI, fig. 45, the bundle is unquestionably encased in a small cylinder of delicate cells,  $f''$ , which are elongated parallel to the bundle. In the specimen Plate X, fig. 44, the outer portion of the bundle,  $f$ , the basal part of which is similarly, though less conspicuously, invested, has entered the interior of the rootlet, as is also the case with the corresponding bundle of the central rootlet of Plate VIII, fig. 15.

A tangential section of the bark, crossing a rootlet cushion transversely, as in Plate V, figs. 46 and 47, reveals a mass of very small parenchymatous cells,  $h$ , with the vessels of the rootlet bundle in their centre at  $f$ . In some such sections these cells are distinguished with difficulty from the vessels. The figures of the above sections are enlarged twenty diameters. In Plate V, fig. 48, in which the centre of fig. 46 is further enlarged to 200 diameters, the vessels are seen at  $f$ , whilst a small vacant space at  $f'$  looks as if it had been occupied by the phloem portion of the vascular bundle. Surrounding the cells, figs. 46 and 47,  $h$ , we have a zone,  $h'$ , composed of rather larger cells. In fig. 47 the vessels are undistinguishable from the surrounding cells. Externally to the zone  $h'$  we have in fig. 47 the fusiform cells of the prosenchymatous layer of the bark,  $e$ , through which the rootlet cushion passes radially. In all my sections an extension of the outer layer,  $h'$ , of the

cushion seems to fill a vertically elongated lenticular cavity in the prosenchymatous zone, which cavity reminds us of the forms of the lenticular sections of the primary medullary rays as seen in tangential sections of the vascular cylinder.

Sections made parallel to figs. 46 and 47, but intersecting and successively encroaching upon the basal part of a rootlet, still exhibit the tissue, *h*, though in circles of decreasing diameter, until we reach the conical apex of the cushion (Plate X, fig. 44, *h''*), when it disappears. Longitudinal sections of the base of the rootlet reveal the existence of a thin layer of a very peculiar tissue springing from the entire conical surface of the cushion. It is composed of elongated branching tubular cells, having a diameter of from  $\frac{1}{800}$  (.0012) to  $\frac{1}{1600}$  (.0006) of an inch. A few detached examples of these cells are represented in Plate X, fig. 50. The cells being frequently much disorganised, I was long ignorant of their true arrangement, but since Plate X, fig. 43, was drawn I have discovered them at the angles, *i i*, of the rootlet cavity, radiating upwards and outwards from the surface of the cushion in parallel lines; the lowest of these lines reach the cortical layer, *g*, of the rootlet; the more central ones, pursuing a parallel upward and outward course, have been merged in the cells of the zone (Plate IX, fig. 51, *g'*) of this part of each rootlet yet to be described.<sup>1</sup>

Plate IX, fig. 51, represents a transverse section of the basal portion of a rootlet enlarged 50 diameters. The conical part of the rootlet cushion is intersected transversely, forming the dark-coloured central zone, *h''*, enclosing the vascular bundle, *f*. Externally, we have some of the parenchyma of the root-bark at *d*, within which is the outer or cortical zone of the true rootlet, *g*. The close continuity of the cells of these two zones shows that this section has been made just below the line *xx*, of Plate VI, fig. 45, where the parenchymatous layer of the cortex, *d*, has been bent back upon itself to form the outermost layer, *g*, of the rootlet. That this outermost rootlet layer is merely an extension of the outermost layer of the bark is demonstrated by all the sections in which both are preserved together. Between the two zones, Plate IX, fig. 51, *g* and *h''*, we have the very distinct parenchymatous zone, *g'*, which is not preserved in one section in a thousand,<sup>2</sup> even in this basal portion of a rootlet, its place being almost invariably occupied by white infiltrated mineral matter. It is, however, well preserved in this section, as is also the case in a young longitudinal section of the corresponding part of a rootlet. (Cabinet, No. 746.) The cells of this tissue chiefly range between  $\frac{7}{1600}$  (.00437) and  $\frac{1}{400}$  (= .0025) of an inch in diameter. At

<sup>1</sup> These cells have now been introduced into Plate X, fig. 43, *i*.

<sup>2</sup> It is a noteworthy fact that tissue occupying this position is always absent from the rootlets of *Isoetes lacustris*; but in this plant the rootlet bundle, enclosed in its investing cylinder, becomes finally united by a few cells to the inner side of the cortical wall of the rootlet. This union always takes place on the same side of the *Isoetes* rootlet, viewed relatively to the position of the deep fissure intersecting the base of the stem of this plant.

the inner and outer borders of the zone we find a few cells only about  $\frac{1}{800}$  (.00125) of an inch in diameter. The size of these cells, contrasted with the extreme thinness of their walls, probably explains their almost invariable destruction.

Plate IX, fig. 52, represents the central part, *f*, of fig. 51 enlarged 440 diameters. The xylem of the vascular bundle is seen at *f*; whilst at *f'* we observe a vacant cavity which, interpreting this section by others made further away from the base of the rootlet, we may regard as having been occupied by the phloem elements of the bundle, whilst the cells, *f''*, correspond to those indicated by the same symbol and immediately surrounding the bundle in Plate V, fig. 48.

In most of the transverse sections of these rootlet bundles made like Plate V, figs. 46 and 47, where the latter are passing through the inner and broader portion of the rootlet cushion, the elements constituting the vascular bundle appear to have their morphological arrangements modified by their contact with the tissue surrounding them. But we find that a change takes place as soon as, if not before, the bundle escapes from the apex (Plate X, fig. 44, *h'*) of the cone of the cushion; sections of the bundle at and beyond this point assume the features that characterise them throughout the entire length of the free part of the rootlet. These features are seen in all the bundles represented on Plate XI; but before dealing with them some other points demand attention. The moment the bundle escapes from the apex of the cushion cone, within the rootlet, we find it encased within a small cylinder (Plate X, figs. 43 and 44, *f'*) composed of linear rows of small parenchymatous cells. These cells are usually as broad as long; but sometimes, as in Plate IV, fig. 53, the innermost of them, *f'*, are more elongated. This figure represents a longitudinal section of a portion of a small bundle, *f*, enlarged 100 diameters. Owing to the absence of all tissue from the rootlet cavity, *g'*, the bundles and their sheaths rarely occupy their normal position in the centre of these rootlets, but are usually more or less excentric.

#### GROWTH OF THE ROOTLET BUNDLE.

We have already seen, from such sections as Plate VI, fig. 9, that the deflection of its vessels to form rootlet bundles took place simultaneously with the first appearance of a rudimentary vascular cylinder; and that as the cylinder increased in diameter by the addition of centrifugal exogenous growths, a corresponding increase took place both in the diameter of the bundle and in the number and size of its component vessels. Transverse sections of free rootlets demonstrate the order of that development. After collecting and carefully weighing all available evidence, I conclude that the number of the rootlets given off from a Stigmarian root was finally determined during the youngest stage of the development of that root; no addition to that number being made during its subsequent growth. It is at first



difficult to believe that a large root several inches in diameter does not possess more rootlets than a small one whose diameter does not exceed a minute fraction of an inch. Yet series of tangential sections, made from successive planes of a vascular cylinder, display exactly the same number of such bundles, whether such sections are made close to the medulla, or in immediate contact with the cortex. The primary medullary rays through which these rootlet bundles emerge differ in this respect from the secondary ones. The former do not increase in number with age. The latter do so indefinitely. The two modes of growth, viz. individual dilatation and meristemic multiplication of their elementary tissues, have caused each individual rootlet to increase in size; the same actions, taking place simultaneously in the bark upon which the rootlets were planted, pushed those rootlets further and further apart from one another, as is demonstrated by Plate III, figs. 6, *a*, and 6, *b*.

Thus, some rootlets in my cabinet have only a diameter of  $\cdot 025$ , others reach  $\cdot 4$ , the latter being sixteen times larger than the former, without any change whatever being made in their characteristic organisation. We shall see, what was first demonstrated in my 'Memoir,' Part XI, p. 291—93 ('Phil. Trans.'), that this increase in the diameter of each rootlet is accompanied by an approximately corresponding increase of the number and diameters of the vessels forming the rootlet bundle.

Plate XI, figs. 54 to 61, *f*, represent transverse sections of vascular bundles from within the interiors of rootlets of different ages, each with more or less of its investing cellular cylinder, *f*, and all equally enlarged 100 diameters. The differences between the magnitudes, both of the bundles and of their investing sheaths are seen when we contrast figs. 54—6 with 58. In fig. 54, *f*, the formation of the bundle begins with three extremely minute vessels or Tracheids (*f''*) closely combined at one point of the wall of the investing cellular sheath, *f'*; to which vessels a fourth larger one, *f*, has been added centripetally. In fig. 55 a similar arrangement exists, only we have here a fifth and yet larger vessel, *f''*, added to the inner side of *f* of fig. 54. In fig. 56 we have five Tracheids, between which number and what we see in fig. 57 any number of examples could have been figured. Thus far the absolutely monarch character of the vascular bundle is clear.<sup>1</sup> In fig. 57 the equally monarch bundle, *f*, is greatly increased in size contrasted with figs. 54—6. It now consists of at least eleven vessels, the smallest of which, *f''*, retain their monarch character as definitely as their representatives, *f''*, in fig. 54. The large size of the newer vessels, *f*, is conspicuous, and a similar enlargement is seen in the cells of the sheath, *f'*. In fig. 59 the number of the Tracheids has increased to fifteen, and in fig. 58 to sixteen. All the last three figures show the bundle to be as independent of the surrounding cellular sheath, except at the point

<sup>1</sup> This point is interesting viewed relatively to an opinion entertained by M. van Tieghem respecting the origin of similar bundles amongst recent Lycopods, to which attention will again be directed.

of primary orientation,  $f'$ , as in the three preceding smaller figures. In fig. 59 we see at  $f'''$  two vessels somewhat detached from the next one,  $f''$ , and more deeply embedded amongst the cells of the investing cylinder than is usual; nevertheless, these three linearly arranged Tracheids, along with those at  $f'$  constitute the monarch point, to which the remaining vessels of the bundle were added centripetally. In figs. 60 and 61 a further increase in the same direction is seen. There are about sixty-four vessels in fig. 60 and seventy-five in fig. 61; the apparent adhesion of the left-hand side of the bundle to the bundle sheath in fig. 60 is merely accidental, not organic. The only material changes to be noted are that the section of the latter bundle has become increasingly wedge shaped, and the newer Tracheids,  $f''$ , are more obviously arranged in radiating series than are the older ones,  $f'$ , changes which are yet more conspicuous in fig. 60. It is important to note that every intermediate condition exists between the pyriform bundles of figs. 57 and 58 and the wedge-shaped bundles of figs. 60 and 61, since M. Renault has attempted to show that these extreme modifications of a graduated series represent important morphological and functional distinctions; a subject to be discussed immediately. Equally important is the fact that each bundle commences its growth from a single point,  $f'$ , not at three points, as is affirmed by M. Renault; nor yet at two semi-contiguous points, which become one by coalescence, as M. van Tieghem believes to be the case with the representative bundles in the roots of living Lycopods.<sup>1</sup>

We now know that on its primary appearance in any young root, the vascular xylem almost invariably takes the shape of two or more groups of minute vessels, symmetrically arranged round the periphery of a central cylindrical strand of small meristematic cells. Sachs has designated this axial strand a procambium, Nägeli a cambium strand, Russow a desmogen, and De Bary an axial meristematic or initial strand of a vascular bundle. The number of initial vascular points varies much. But the number is conveniently designated by the terms monarch, diarch, triarch, &c., whatever that number may be. The peculiarity of these initial vascular points is that additions are made to them centripetally, until, in many cases, these additional growths meet in the centre of the young root, occupying, more or less completely, the medullary area. The name of *xylem plates* is given to these vascular growths. Midway between these several initial points, or points of orientation, we find small patches of phloem.

This question only concerns us now so far as it affects our study of the Stigmarian rootlets, which it does very materially, because of distinct peculiarities

<sup>1</sup> Of late years the primary structure and ultimate development of roots has attracted a large amount of attention amongst the most distinguished European botanists. An important memoir by M. van Tieghem ('Recherches sur la symétrie de structure dans les plantes vasculaires. 'Annales des Sciences naturelles,' 5me série, tome xiii) has done much to stimulate further inquiry into the subject.

displayed by them, in common with the roots of living Lycopodiaceous plants and of Ophioglossum. In most of the former and all the latter we only find one xylem plate opposed to, or more or less surrounded by, one phloem element. Hence these living roots are unmistakably monarch. M. van Tieghem, finding that where a rootlet dichotomises its bundle divides into two, one half going to each of the secondary branches, came to the conclusion that the monarch appearance of such a bundle was due to the fact that it had divided in order to supply two branches, *one of which had become abortive*. M. van Tieghem's conception seems to be that two xylem and two phloem plates initiated so near to each other that the two xylems blended to form one, and that the two phloem strands did the same. I have never been able to accept this explanation, because of the contradiction which the rootlet bundle of Stigmara gives to it. De Barry affirms that there is no basis of fact for it.<sup>1</sup>

The history of the development of the xylem plate in Stigmara makes it clear that it is absolutely monarch. Every stage of that development, whether we study its orientation in the vascular cylinder of the root, its appearance within the root-cortex, or its final structure within the rootlet itself, leads us to the same inevitable conclusion. And the establishment of this conclusion respecting what was indisputably a primæval Lycopodiaceous rootlet, may react upon our interpretation of the same organisation in its living representatives.<sup>2</sup>

The rootlets of Stigmara, springing from the axial root, always incline more or less, as they grow, towards the growing end of that axis, enclosing a more or less acute angle as they do so. The first formed Tracheids of the young rootlet bundle ( $f''$  of Pl. XI, figs. 55, 57, and 58) always originate on the side of the rootlet nearest to the growing tip of the root. This relationship is absolutely constant. We have already seen from Pl. VI, fig. 9,  $f$ , that some of the vessels and Tracheids successively added exogenously to the entire exterior of the xylem cylinder, are prolonged into each rootlet bundle. Such additions to a bundle are always made on the side of it that is turned from the growing tip of the root. Hence in all sections of these rootlet bundles, like Pl. V, fig. 16, the vessels  $f''$  represent those first formed, whilst  $f$  indicates the newest additions. We have here a second absolutely constant relation. The growth in thickness in each rootlet bundle was steadily upwards and outwards from an inner and lower monarch starting-point. The small Tracheids seen at  $f-f$  of Plate IV, fig. 31, instead of being two additional points of orientation of a triarch bundle, are really amongst the latest additions to

<sup>1</sup> 'Comparative Anatomy of the Phanerogams and Ferns,' English translation, p. 561.

<sup>2</sup> M. Renault having observed examples like my figs. 57 and 59, Plate XI, in which a few of the Tracheids,  $f'''$ , last added centripetally to the rootlet bundle of Stigmara, were very small, arrived at the conclusion that their relations to the surrounding bundle cylinder were as primary as those of the Tracheids marked  $f''$  in my figures 57 and 58; in other words, he believes that these bundles are triarch. Their entire history completely contradicts this interpretation.

that bundle, and their smaller size is due, as has already been explained on p. 22, to the fact that they have been derived from a younger layer of half-developed Tracheids like that seen at *b'* in Plate IV, fig. 19.

An invariable vegetative repetition of so complex an organisation as I have now described appears to be absolutely incompatible with the possibility of some of the organs so constructed being phyllomes and others caulomes or emergences from caulomes. That members with such different functions as leaves and roots should possess so absolutely identical a structure, form, and direction of growth seems to me too absurd to be conceived.

In several instances I have met with clusters of rootlets, a transverse section of one of which is represented in Plate XIII, fig. 79, where each rootlet has a thin longitudinal cellular lamina, fig. 79, *f''*, looking like a centripetal extension of the outer cortex, *g*, of the rootlet, and connecting that cortex with the bundle cylinder, *f*. In many such examples the lamina appears to join the bundle cylinder exactly opposite the point of departure of the bundle from its cylinder. I am not yet, however, quite sure that this is a constant relationship between the position of the lamina and the acropetal side of the rootlet.<sup>1</sup>

Plate XI, fig. 62, is a transverse section of a young rootlet with only three or four xylem Tracheids, *f*, but we find at *f'''* the phloem cells of the bundle occupying the position which I have assigned to the phloem in Plate V, fig. 48, *f'*, and Plate IX, fig. 52, *f'*.

Plate XIII, fig. 27, and Plate XI, fig. 63, illustrate another feature occasionally seen in these rootlets. Artis long ago represented some which were dichotomous at their free extremities,<sup>2</sup> and Corda figured a similar example.<sup>3</sup> Plate XIII, fig. 27, represents a similar dichotomous form, such specimens being occasionally met with in our Lancashire deposits. Besides this my cabinet contains several transverse sections of what have been rootlets either preparing for or actually undergoing similar dichotomy. Plate XI, fig. 63, *g*, represents the inner surface of the external cortical zone of the rootlet, within which is the usual fistular cavity, *g'*. But at *ff* we have two bundles that have originated from the subdivision of a primary one, each being enclosed in its separate bundle cylinder, *f'*. The cortical zone, *g*, has not yet shared this dichotomy, but in another of my sections it has done so. In it a broad belt of the cortical tissue *g* has extended completely across

<sup>1</sup> M. Renault has figured a rootlet bundle with its bundle sheath, from the exterior of which a similar cellular band radiates; but he thinks he sees in the specimen evidence that a lateral branch (*radicelle*) springs from the rootlet as well as that the rootlet bundle is double, half of which is developed centripetally, and the other half centrifugally. Nothing of this kind exists in any one of the innumerable rootlets in my cabinet. That a few of them dichotomise is shown in Pl. XIII, fig. 27, but such dichotomy is invariably truly terminal, not lateral or monopodial.

<sup>2</sup> 'Antediluvian Phytology,' *Ficoidites furcatus*, Pl. iii, A, B.

<sup>3</sup> 'Flora der Vorwelt,' Taf. xii, fig. 1, A.

the section, dividing it into two areas, each of which has a bundle and bundle sheath, like those of fig. 63, in its centre. On the other hand, a section of a third rootlet displays the bundle divided into two, but even the bundle sheath has not yet begun to divide. All these arrangements correspond very closely to what we find in the branching rootlets of recent Lycopods. In the specimen figured by Artis, as well as in my fig. 27, the two branches appear to be joined to the primary one by oblique articulations; but I find no trace of these in my sections. They were probably mere constrictions of the cortical layer. In one section of a rootlet in my cabinet the bundle is enlarged laterally in a fan-shaped manner, as if preparing to divide. A union of the two bundles of fig. 63 would produce a very similar contour to that seen in the above specimen. It appears as if this slight tendency to dichotomous branching, manifested by the Stigmarian rootlets, was the forerunner of what became a normal condition amongst recent Lycopods.

Plate X, fig. 42, represents a transverse section of a large rootlet, *g*, into the interior of which six smaller ones have forced their way, in doing which they have squeezed the true vascular bundle and its cylinder, *f*, of the invaded rootlet into a corner. This example affords a good illustration of the extraordinary way in which these rootlets penetrated openings, large or small, in any vegetable fragment within their reach.<sup>1</sup>

<sup>1</sup> M. Renault has figured a similar specimen in his "Étude sur les Stigmaries, Rhizomes et Racines des Sigillaires," *Annales des Sc. Géol.*, xii, 1, Pl. ii, fig. 1. Describing this specimen, he designates the invaded rootlet as a leaf, whilst the invaders are admitted to be true rootlets. But he gives no adequate reason for thus applying different names to things that do not differ. Comparing his figures with similar specimens in my cabinet, I can only conclude that, misled by a foregone conclusion, he has allowed himself, in his pages 24—30, to be drawn into a confused maze of errors. He does not deny that his leaves and his rootlets have the same external forms and internal organisation; the supposed difference to which he trusts in distinguishing leaves from rootlets being in the form of sections of their vascular bundles. It would be needless further to discuss a question with which I have already alluded on p. 22, were it not for the important conclusions which M. Renault draws from his supposed facts. I have already shown that the two types to which our author attaches so much importance pass by imperceptible gradations into each other, and, I may add, that similar wedge-shaped and non-wedge-shaped bundles exist amongst the rootlets of living Selaginellæ.

But the question assumes importance because it is made the basis of conclusions which set at defiance some of the most fundamental laws of botanical morphology, relating to the positions of members upon a common axis. The pages 24—30 contain a succession of statements which I cannot accept. Describing a section like my fig. 14, Plate VII, he says that the vascular bundles which I have indicated by *f*, *f'*, "ne peuvent être pris pour des faisceaux de racines, dont ils n'ont aucun des caractères" (loc. cit., p. 21). I reply that, without one solitary exception, all those bundles go to those characteristic appendages of the Stigmarian axis which are now so widely recognised as rootlets. The illustrations given in the preceding pages surely demonstrate that point. M. Renault further says: "Nous regardons ces faisceaux comme un portion des éléments vasculaires destinés à des appendices foliaires" (loc. cit., p. 22). We are thus carried back to the days of Artis, Corda, and the 'Fossil Flora of Great Britain.' The labours of Brongniart and Hooker, of Binney and Dawson, along with those of a host of other observers are all to be cast aside as worthless. Before thus returning to the dark ages of Carboniferous

There still remain for consideration some fragments of *Stigmaria* which, though not capable of microscopic examination, could not have been interpreted without the knowledge which we owe to the microscope.

palæo-phytology, I ask for some proof of the necessity for taking so extraordinary a backward step and I am referred to some insignificant differences in the forms of the transverse sections of some small, variable, vascular bundles. After other equally inaccurate statements respecting some morphological details, M. Renault says: "Le deuxième ordre de faisceaux offre sur un section transversale la forme de triangle équilatère ou scalène. Fig. 2 et 6." "On distingue facilement sur deux ou trois points, *a*, de la périphérie du faisceau, des trachéïdes de petit diamètre, celles du centre étant beaucoup plus larges, la section de ces dernières est trois à quatre fois plus grande que celle des éléments qui composent l'ensemble des faisceaux du premier ordre décrit plus haut, et que nous regardons comme appartenant à des organes foliaires; de plus, les trachéïdes ne sont pas disposées en séries rayonnantes à partir de l'un des angles du triangle formé par la section, il est donc évident que nous avons affaire à une autre sorte d'organe et que ces cordons vasculaires sont des faisceaux de racines" (loc. cit., pp. 22, 23).

In the above passages M. Renault enumerates what he regards as three distinctive characters, by means of which he recognises rootlet bundles. First, the unequal diameters of the Tracheids; secondly, the triangular form of the section of the bundle, and lastly, the absence of a radiating arrangement of the vessels composing the bundle. It must be remembered that the bundles which he thus characterises are, according to him, something distinct from those seen at fig. 14 at *f, f'*, and consequently also distinct from those seen in tangential sections like fig. 8, *f*, of Plate V. That these latter sections merely represent two aspects of the same organ is beyond all question; and since these are the only bundles discoverable within, or arising from the vascular cylinder, we may ask, whence and where do these apocryphal additional bundles arise? Leaving this question, to which we get no answer, we may inquire what value can be attached to the three other points?

1. Non-uniform size of the vessels. That this is a most variable feature I have already pointed out in my previous descriptions. The same bundle varies even in different parts of its course. Thus, in sections like fig. 9 nothing is more common than to find bundles, the Tracheids of which are derived from the larger vertical tissues of the vascular cylinder, reduced to an extremely small size when deflected, as at Plate VI, fig. 9, *f*. I affirm unhesitatingly that variations in the sizes of the vessels composing a bundle cannot be depended upon as a differentiating character.

2. Triangular form of the bundle section. Where the bundles emerge from the cortical surface of the xylem cylinder and plunge into the bark, they almost always present more or less of the triangular or wedge-shaped section; but their arrangement becomes entirely changed as they leave the outer cortex to enter the rootlets, where their transverse sections become more or less pyriform. But besides this general fact, the forms of these sections vary considerably. We find many in which, as in Plate XI, fig. 36, all the Tracheids are arranged radially; we have others, like Plate XI, fig. 61, in which only the outermost ones thus radiate, and others again, like Plate XI, figs. 57 and 58, in which there is no radial arrangement whatever.

Definitions based upon such absolutely inconstant features are always worthless; how much more so when they are depended upon to distinguish organs so widely different, both morphologically and physiologically, as roots and leaves? They would be worthless, even did other facts suggest a probable existence of a combination of rootlets and leaves on the axis of a *Stigmaria*; but when, as is the case here, all the known facts afford demonstrative evidence in the opposite direction, the employment of such variable features, for the purpose of overthrowing the conclusions of two generations of experienced palæontologists, can scarcely be regarded as wise.

In the first place, we have the most absolute vegetative uniformity in the orientation of ALL the

Plate XIII, fig. 64, is an inorganic cast of the medullary cavity of a *Stigmara*, from the Hutton Collection, now in the Museum of the Natural History Society of Newcastle-upon-Tyne. The figure is of the natural size. The diagonal rows of oblong ridges covering the surface of the specimen are casts of the medullary ends of the primary medullary rays of the vascular cylinder.

vascular bundles given off from the axial vascular cylinder of *Stigmara*. Whether we examine transverse sections of that cylinder (Plate VII, fig. 14, *f*), longitudinal radial sections (Plate VI, fig. 9, *f*), tangential sections (Plate V, fig. 8), we arrive at the same conclusion. We find a number of vascular bundles, springing from the vascular cylinder of the axis, in a uniformly characteristic manner. All these bundles pass outwards, through the primary medullary rays specially provided for their transmission, in a geometric order, which is not more disturbed by slight irregularities of growth than is the case with the equally geometric phyllotaxis of recent leaves. When these vascular bundles emerge from the cylinder, to pass through the bark, they all bend downwards (Plate XII, figs. 37 and 39) in true root-like fashion and which is the reverse of the course pursued by all the leaf bundles of *Lepidodendroid* branches. On emerging from the outer bark, with the exception of an occasional derangement, resulting probably from the arrested development of some rootlet when in a very young state, the quincuncial arrangement of these rootlets in diagonal lines again becomes geometric. Turning to the structure of the rootlets, whose origin and course alike illustrate vegetative repetition in one of its most mechanical forms, we find that they display no material variation in the structure that is so characteristic of them. The rootlet bundle is *invariably* monarch in its orientation; its point of orientation is *always* acropetal in relation to the growing root upon which each rootlet is planted.

In the face of facts like these, still to insist that structures, which are so obviously vegetative repetitions of one another, develop into a confused medley of rootlets and leaves, has no claim to rank as a scientific inference. It becomes a mere preconceived idea adhered to in the face of an overwhelming array of opposing facts.

Unfortunately the mischief does not end here. What I have given my reasons for regarding as errors of observation have led M. Renault to other conclusions equally unjustified by any known facts.

In his 'Cours de Botanique' he has a paragraph headed "Mode de Croissance des Sigillaires" (loc. cit., pp. 162, 163, 164). I regard this paragraph as full of unsupported hypothetical statements. All our experiences in Great Britain, Canada, and the United States, in each of which countries Sigillarian and Lepidodendroid stems with Stigmarian roots are abundant, give to these hypotheses an unqualified contradiction. No solitary instance can be shown in any of these countries in which "l'extrémité d'une branche de *Stigmara* se relevait en bourgeon aérien." Even Brongniart tells us of "l'absence de toute apparence d'un bourgeon terminale" ('Tableau des Genres de Végétaux fossiles,' p. 56). It is unfortunate for science that M. Renault should hold such views unless he could support them by more conclusive proofs than he has hitherto recorded. When we find these views receiving the degree of countenance and circulation which MM. Saporta and Marion have given to them in their recent work, 'L'Evolution du Règne Végétale,' the matter becomes still more serious. It is the support thus given to these retrograde opinions that in 1883 led Sir William Dawson to say, half despairingly, in his address to the American Association for the Advancement of Science, "Some one will have to rescue from total ruin the results of our labours."

I claim no monopoly of the knowledge of what is true; but I am entitled to ask that when a considerable number of practised observers, after many years of careful investigation, arrive at certain definite conclusions, those conclusions should not be lightly disturbed. To justify such a course, the disturber should be prepared with such strong evidence as very definite facts alone can furnish. Such facts, I contend, M. Renault has not yet laid before us. In their place we have only got opinions!

Plate XIII, fig. 65, is part of a fragment of a *Stigmara* from a sandstone bed in the Mountain Limestone district of Weardale. When broken longitudinally the specimen, fig. 64, was found loose in the cavity, 65, *b*. Both these specimens were figured in Lindley and Hutton's 'Fossil Flora of Great Britain,' vol. i, pl. 35. The concave surface, 65, *b*, was supposed by the above authors to be merely a cast of the exterior of fig. 64, which latter was regarded as "a woody core communicating by means of woody elongations with the tubercles on the outside; this core has evidently contracted, since the plant was embedded and now lies loose in the cavity of the stem" (loc. cit., p. 106). This sentence affords a fair example of the errors to which observers are liable when interpreting specimens of the histology of which they are ignorant. As we have just seen the supposed "woody core" is but an inorganic cast of the hollow *interior* of the true woody cylinder, the *external* surface of which cylinder is represented by the concavity, *b*. This cast of the latter surface displays the peripheral ends of the primary medullary rays where the rootlet bundles escaped from the cylinder to enter the bark. All the tissues between that cylinder and the outermost surface of the cortex have disappeared, being replaced by the inorganic material, *d*, which has moulded itself upon the cylinder. The exterior of this specimen shows the characteristic rootlet-scars.

Fig. 66 is a second specimen resembling fig 65, also from the Hutton Collection but which shows much more distinctly than the last does, the casts of the oblique lines of large external orifices of the primary medullary rays. As in fig. 65, all the cortical tissues have disappeared, and were replaced by soft sedimentary mud before the tissues of the vascular cylinder were decayed. This latter member also disappeared ultimately, both in figs. 65 and 66.

Plate XIII, fig. 67, is a transverse section of a *Stigmara* root from which all the original organic elements have disappeared, the woody wedges of the vascular cylinder, *b*, having been the last to do so. The inorganic sediment has here occupied not only the whole of the cortical area but also the central medullary cavity and the primary medullary rays, *b'*, radiating from that cavity. The woody wedges are now only represented by the dark, vacant spaces, *b-b*. Specimens like this and the three just described are instructive. They demonstrate how superimposed layers of tissue may have disappeared, not simultaneously, but in succession, and their places have been occupied by inorganic materials in a similarly successive manner. Some of these materials have been introduced in a plastic state, like those filling the areas *a* and *d* of fig. 67; but, had cavities like those left by the decayed wedges, *b*, of fig. 67, instead of being left empty, been filled subsequently to the replacement of the other structures, *a* and *d*, by plastic sediment, this could only have been done by mineral matter in solution and capable of filtering through the clay. It has been such a deposition from infiltrated solutions that has occupied



not only the interior of most of the Stigmarian rootlets figured in this Memoir, but also of almost every cell and vessel found in the deposits from which a large majority of my specimens have been obtained.

Plate XIV, fig. 68, is a specimen of a root, split vertically, drawn four-fifths the size of the original, for which I am indebted to Professor Green of Leeds. Its unseen exterior surface is furnished with the usual rootlet-scars. At *a* is the external surface of the inorganic cast of the medullary cavity, exhibiting, though rather more closely aggregated, longitudinal ridges like those seen in Plate XIII, fig. 64. The well-defined longitudinal section of the vascular cylinder, *b b*, is transversely subdivided into small square areas by the primary medullary rays, *b'*, which radiate through the cylinder at right angles to its axis. The medullary cavity and all the cortical zones are alike replaced by inorganic sandstone.

Plate XIV, fig. 69, is a specimen from the Burntisland deposit, represented of its natural size. This specimen would perplex an observer unfamiliar with the internal structure of Stigmara. It is the well-preserved external surface of a large vascular cylinder, exhibiting very definitely the lenticular external terminations of the primary medullary rays, *b b*, but amongst these are a few rootlet-scars, as seen in the next specimen, fig. 70.

Plate XII, fig. 70, is also a fragment of the exterior of a compressed vascular cylinder, wholly composed of barred vessels or Tracheids; but in it the primary medullary rays are indistinctly shown. Forced rather deeply into its substance are several rootlet-scars, *g*, arranged in their normal diagonal lines. Such a specimen, seen apart from others, would inevitably indicate the direct orientation of the rootlets from the vascular zone. What has occurred is obvious. The whole of the cortical tissues have disappeared, but with so little disturbance that, on both sides of the specimen, the bases of the several rootlets have become impressed upon the exterior of the flattened vascular cylinder, without any derangement of their normal relative positions. Such specimens teach caution ere we conclude that, because two tissues are found in the closest possible contact, they must once have been organically united.

Plate XIII, fig. 71. An impression on shale from the Hutton Collection. It is part of a dichotomising root, the surface of which exhibits, besides its rootlet-scars, parallel longitudinal ridges, which either represent fissures in the original bark, or elevations due to shrinkage; between these ridges are fine undulating lines, also running longitudinally, which also appear to have been caused by a shrivelled state of the cortical surface. Another similar specimen, also from the Hutton Collection, exhibits these latter lines; but, in place of the coarse longitudinal ridges of fig. 71, it has numerous strongly marked undulating ridges and furrows running transversely across the fragment. Varied modifications of the surface, especially in specimens of the larger roots from which all rootlet-scars

have disappeared or are disappearing, are innumerable, and have no specific signification. The above figure is half the size of the original.

Plate XII, fig. 72. A cast of the outer surface of a small fragment of Stigmarian bark in which the spaces between the rootlet-scars are occupied by still more strongly marked undulating longitudinal lines. This seems to be the condition to which Goeppert gave the name of *Stigmaria undulata*. The original is in the Museum of the Owens College. I have seen similar specimens with corresponding undulation, but so faintly preserved as to show that they merely represent another of the variable conditions of preservation just referred to.

Plate XIV, fig. 73, is a Stigmarian fragment displaying the more normal conditions of the rootlet-scars; they are depressions, disposed in diagonal lines, producing what is known as the quincuncial arrangement. The large central cavity, *b*, is, like that of Plate XIII, fig. 65, the result of the disappearance of the vascular cylinder from its medullary interior.

Plate XII, fig. 74, is a small fragment of Stigmarian bark from near Oldham, represented of the natural size. Since the tissues of the outer bark as well as of the bases of the rootlets occupying the bottoms of the sunken scars are preserved in this specimen, it becomes instructive, teaching the true histology of those depressed scars, and showing how the rootlets themselves have disappeared. At the outer margin, *g*, of each of these depressions we see the remains of the outermost or cortical zone of the base of each rootlet. Within this outer circle we have the still deeper depression, *h*, produced by the disappearance of the second delicate parenchyma, *g'*, of Plate IX, fig. 51. At the bottom of the latter depression we see traces of the apex of the rootlet cushion, *h'*. Specimens like this clearly show that there has been no kind of "articulation" where the rootlet was planted upon the bark. There was no definite plane corresponding to the cicatrix left by a fallen leaf at which the rootlet separated from the bark. The separation was the result either of external force or of decay, producing a variable contour in what remained of the *torn* tissues of the rootlet. The rootlets of the living *Isoetes lacustris* illustrate this tendency to detachment by rupture, as contrasted with disarticulation.

Plate XIV, fig. 75, is an unusually fine specimen, from the neighbourhood of Newcastle-upon-Tyne, for which I am indebted to the kindness of Professor Lebour. Similar examples have been figured both by Sir Joseph Hooker<sup>1</sup> and by Mr. Binney,<sup>2</sup> but both these authors have fallen into the same error in their interpretations of their specimens. Each of them supposed that the surface which he figured was the true exterior of the bark, whereas it was exactly the reverse; it

<sup>1</sup> Memoirs, 'Geol. Survey of Great Britain,' vol. ii, part ii, pl. ii, figs. 1, 2, and 3, 1848.

<sup>2</sup> 'Carboniferous Flora,' part iv, *Sigillaria* and *Stigmaria*, pl. xxiv, fig. 1, Palæontographical Society, 1875.

was merely the cast or impression of that exterior. They regarded the little projecting circles corresponding to those of my fig. 75, as identical with those of my Plate XII, fig. 74, believing the former to be the portions of the bark upon which the proximal ends of the rootlets were planted, whereas they are the actual proximal ends of those rootlets. Specimens in my cabinet demonstrate that such is the case, since in them the remaining distal part of each rootlet is seen passing backwards through the stone to its opposite surface.

A glance at the diagram of a longitudinal section of a rootlet with a portion of the bark upon which it is placed (Plate XII, fig. 76) will probably make the history of the specimen, fig. 75, intelligible. A fragment of such a bark has been reduced to the condition seen in Plate XII, fig. 74. That this occurrence took place is shown by the fact that casts, which I have made of the surface of that specimen, correspond almost exactly with what we see in Plate XIV, fig. 75. The outer surface of the supposed bark was undisturbed, as at fig. 76, *d'*. Each long rootlet, 76, *g*, had either decayed from its tip backward or had been abruptly broken off near the surface of the bark, where a little of the outer cylindrical wall of each rootlet stood in relief, as at fig. 76, *g'' g''*, forming a funnel-shaped cup, as in Plate XII, fig. 74, *g*. At the bottom of this cup there would project the cone of the rootlet cushion, as in the section Plate X, fig. 44, *h'*; embedded in mud, the future matrix of the specimen fig. 75, that mud would fill the cavity, fig. 76, *g'*, and also surround its external wall and invest the outer surface of the bark, *d'*. The unshaded paper to the right of the bark surface, *d'' d''*, thus represents the outlines of a section which would be identical with a similar section made through one of the rootlet bases of Plate XIV, fig. 75.

Plate XII, fig. 40, is a *Stigmaria*, the interpretation of which was not easy on a merely casual glance. The fragment is but a portion of a much larger specimen, almost identical with, and from the same locality as, that from the interior of which fig. 39 was extracted. We see from fig. 38, which represents the upper end of fig. 39, that all the vascular tissues of that cylinder are well preserved; but both vascular and cellular tissues have disappeared from the area, *ff* of fig. 40, with the exception of a confused mass of vascular bundles; these are evidently the remains of such portions of rootlet bundles as passed through the bark, like those seen on the exterior of fig. 39, but which were left exposed on the decay of the cortical tissues. At fig. 40, *g g*, the rootlets of one side of the specimen pass outwards to the right hand, each in a flattened condition. The surface *d* is a cast of the outside of the bark opposite to that which supplied the rootlets, *g g*. The rootlets of *d* have not collapsed and become flattened after they were invested by the then plastic matrix, though they subsequently disappeared, leaving empty cylindrical cavities which pass downwards and outwards through the stone. In several of these cavities the vascular bundle of each rootlet can still be detected, and two or three of the rootlet cavities present similar

conditions to those seen in Plate XIV, fig. 75, with the morphology of which this part of Plate XII, fig. 40 is almost identical.

Plate XIV, fig. 77, is another of the many variable conditions in which we find the external surface of a *Stigmara*, and which were largely due to the shrivelling of the specimen before its immersion in its muddy matrix, followed by external pressure. Its configuration is virtually that of Plate XII, fig. 74.

Plate XIII, fig. 78, represents a fine fragment in the Museum of the Natural History Society of Newcastle. It is undoubtedly a portion of the plant to which Goeppert gave the name of *Stigmara stellata*,<sup>1</sup> though the rootlets given off from the large symmetrically arranged tubercles are much less perfectly preserved than in Goeppert's specimen. That this object has been a root with rootlets very similar to those of *Stigmara ficoides* appears probable. Whether or not it can be generically united with *Stigmara* is doubtful. We have other plants in the Coal-Measures furnished with succulent rootlets besides *Stigmara*, e.g. my genus *Amyelon*. It appears to me that no plant should be regarded as a *Stigmara*, the internal organisation of which is not at least typically identical with that of *S. ficoides*, and which consequently may be regarded legitimately as the probable root of some *Lepidodendroid* or *Sigillarian* stem. We have no proof that either the one or the other of these affinities exists in the object in question; hence, whilst recognising its unquestionable specific distinctness from *Stigmara ficoides*, I should prefer for the present to refer to it as *Stigmara* (?) *stellata*. The Newcastle specimen was apparently derived from one of the Gannister beds. I have more recently received from Mr. Kidston, of Stirling, a cast of another similar specimen, found loose in a Boulder Clay at Town-Head, Riccarton, in Ayrshire, by Mr. P. Wright, of Galston.

#### CONCLUSIONS.

Having now described all the more important morphological and histological features of the *Stigmarian* root which I have thus far observed, some questions arise connected with its relations with other plants, extinct and living.

The fact that large quantities of *Stigmarian* fragments have been found in several localities unassociated with any *Lepidodendroid* or *Sigillarian* stems has led some geologists<sup>2</sup> to "consider *Stigmara* as originally representing floating stems becoming roots under peculiar circumstances."

We find nothing in Great Britain which supports this or any similar conclusion. Hence British geologists are unanimous in regarding *Stigmarae* as the roots alike

<sup>1</sup> 'Die Gattungen der fossilen Pflanzen,' tab. x, fig. 12, 1841.

<sup>2</sup> *E. g.* Lesquereux, 'Coal Flora of Pennsylvania,' vols. 1 and 2, p. 509.

of *Lepidodendra* and of *Sigillariæ*; and they are equally unanimous in believing that these primæval *Lycopodiaceæ*, found in the Devonian, Carboniferous, and Permian strata, are the remote ancestors of the modern *Lycopodiaceæ*. The question arises how far does our present knowledge respecting the morphology and histology of these ancient arborescent forms enable us to detect connecting links between them and their degraded living descendants.

That the dichotomous ramifications of the branches, the structure and arrangement of the leaves, and the entire morphology of their reproductive organs, furnish such links is indisputable. But we are now familiar with other morphological features presented by these ancient types, the relations of which to those of living ones are not quite so clear.

That the axial vascular strand of the living *Lycopodium* and *Selaginella* is the homologue of the non-exogenous inner vascular zone of *Lepidodendron* can scarcely be doubted. In both cases these tissues constitute the only axial vascular elements possessed by the youngest branches on which all the leaves are developed, and to which leaves they supply the only vascular bundles that those leaves ever possess.<sup>1</sup> These ancient and modern vascular axes also agree in their mode of growth which is in both cases centripetal.

There can be equally little doubt that the rootlets of *Stigmaria* correspond to those of living forms, both in their structure and their acropetal order of development. The vascular bundle in the centre of the *Stigmarian* rootlet, as well as the cellular zone which invests it, is almost identical with that of *Selaginella*, and approximates still more closely to that of *Isoetes*. In two respects the affinities of the *Stigmarian* rootlets with those of *Isoetes* are remarkable. In both organisms these rootlets are given off from the lower part of a downward prolongation of a caulome, which prolongation never develops leaves; the rootlets, therefore, are produced upon an axis which grew in the opposite direction to that in which the leaf-bearing part of the stem grew. In addition to this, the rootlets of *Isoetes* and of *Stigmaria* agree in the circumstance that, in both, they are converted, during life, into fistular cylinders, owing to the disappearance or non-development of the delicate parenchyma, which ought to occupy the space between the outer cortical layer and the investing sheath of the central vascular bundle. But important differences have been produced by the introduction, into both the stems and roots

<sup>1</sup> M. Renault's idea that in the many extinct forms which possess a diploxyloid vascular axis, *i.e.* an inner centripetal and an outer exogenous axis, each of these two cylinders contributed to the formation of the leaf-bundles, cannot be accepted. In *all* cases the leaves and their leaf-bundles were developed before any exogenous zone made its appearance; and in several known *Lepidodendroid* plants the branches attained to a large size before any such zone began to grow. To suppose that, in such cases, the leaves had to wait for their complete vascular structures until, having done their chief work, they were ready to be cast off, is impossible. Hence I must reject this assertion that the foliar bundles had a double origin, as it is alike contrary to probability and to observed facts.

of the extinct forms, of a true, exogenously developed, vascular cylinder. This zone with its radial laminae of vessels, its true medullary rays, and its meristemic cambium zone, encloses the vascular, axial strand which supplied the vascular bundles to the leaves. These leaf-bundles were all fully developed, and extended continuously through the bark, from the axial vascular strand from which they originated to the leaves on the surface of each twig, before (in many cases *very* long before) the exogenous cylinder made its appearance. Hence when the first-formed vessels of that cylinder arranged themselves longitudinally round the central axis from which the leaf-bundles emerged, they had to bend round each of the many foliar-bundles that stood in their way, coming together again when they had passed the obstruction. This was also done by each successive exogenous growth without any contribution being made by the latter to the foliar-bundle. Each additional exogenous layer pursued the course followed by that upon which it rested. Hence each foliar-bundle passed outwards through the exogenous cylinder, along horizontal lenticular passages, the vessels enclosing the peripheral portions of which passages were successively superimposed upon the pre-existent bundles. These relations of consecutive, not coeval, origin explain what observation demonstrates to be a fact, viz. that the exogenous cylinder was a vascular network, through the meshes of which the foliar-bundles continued to reach the bark, but without receiving any additional vascular contributions.

This exogenous zone made its first appearance in the various *Lepidodendroid* trees at very different stages of their growth. In the *L. selaginoides* of Halifax we find it existing even in very young twigs. In the *Burntisland Lepidodendron* it appears, not in the twigs, but in young branches. In the *Arran Lepidodendron* from Laggan Bay, no traces of it are seen until the branches have attained to a large size. It evidently began to be developed at the junction of the stem with the root of each plant; attaining to a greater relative importance in the latter than in the former organs, since we find it, as shown by Plate IX, fig. 18, reaching the extremities of the true roots, which it never does in the twigs. Since every rootlet derived its vascular strand from this layer, and since rootlets were obviously furnished to the plant in its youngest state, this early development of the exogenous zone in the roots was a matter of absolute necessity. Such was not the case with the aerial parts of the plant, the leaves of which, as we have seen, obtained their vascular strands independently of the exogenous zone. But the latter evidently crept up the stem from below as a succession of investing cones, each newer investment reaching a higher point than those which preceded it. Now if these views are correct, which I believe them to be, we can understand the functions of the vascular cylinder of *Stigmara*. The mineral and nitrogenous food-material absorbed by the rootlets was conveyed to the stem through the exogenous zone, whence it was transmitted laterally to the

more central, non-exogenous cylinder, through the branches of which it passed to the leaves. Assuming that my morphological data are accurate, about which I have no doubt, the above appears to me to be the only physiological explanation that can be given of the primary functions of the exogenous zone in these giant Cryptogams. In the living Lycopodiaceæ, with the exception of Isoetes, nothing like this arrangement exists. The rootlet bundles are all derived directly from the same central source as the leaf-bundles, the two sets of bundles differing only in the upward direction followed by the former and the downward one pursued by the latter; hence no lateral transference from one vascular system to another is necessary. Another structure introduced into the extinct plants is the bark cambium (Plate VIII, figs. 22 and 23), which has no definite existence in any recent form except Isoetes. In this plant the cortex is more dependent upon a cambial layer and is developed by that cambium in a more conspicuous manner than in any other known plant; but in this instance the same cambium adds centrifugally to the loose axial mass of Tracheids on its inner side, and, centripetally, to the cortex on the outer one. We thus see that the ancient Lycopods had two cambium zones, the functions of the outermost being limited to bark-growth, and the inner one apparently to extension of the exogenous layers, the latter alone being concerned in the orientation of the rootlet bundles. Isoetes, on the other hand, has but one cambium zone which is equally concerned in the orientation of the leaf-bundles, the rootlet bundles, and the development of the bark. Degradation from a higher to a lower type of organisation has been followed by a generalisation of function, instead of the opposite process of multiplication of organs and specialisation of functions which attends progressive evolution. The supremacy of the Carboniferous Lycopodiaceæ over their modern representatives therefore is not limited to their greater magnitude, but includes a more complex organisation.

There appears no doubt whatever that the Stigmaria is found in the Devonian, Carboniferous, and Permian Rocks. In the two former it is in some cases associated with both *Lepidodendron* and *Sigillaria*. But in the Arran Deposit at Laggan Bay, where it was not rare, though we have *Lepidodendroid* branches in profusion, we find no trace of *Sigillaria*. This association is yet more remarkable at the plant-bearing deposit at Burntisland. The rock at that locality is largely composed of *Lepidodendroid* twigs, but has not yet furnished, so far as I know, the smallest trace of a *Sigillaria*. The late Professor Heer tells us that the Spitzbergen deposits supplied *Lepidodendron Veltheimianum*, along with fine and large *Stigmaria*, but no *Sigillaria*. The same author also obtained *Stigmaria* along with several species of *Lepidodendron* at Bear Island, but again no *Sigillaria*; and M. Lesquereux cites Schimper's authority for the fact that a deposit in the Vosges is "filled with a prodigious quantity of fragments of *Stigmaria* without trace of any *Sigillaria*," but adds significantly, "that these strata contain abundant remains or trunks of

Knorria and Lepidodendron." It is needless to add that all these cases only point to the fact that the Lepidodendra had Stigmarian roots as well as the Sigillariæ.

This abundance of Stigmaria apart from Sigillariæ has been referred to by more than one writer as a proof that Stigmaria was sometimes an independent plant *sui generis*. The reply is obvious. We have abundant proof that, wherever we obtain a Stigmaria connected with any aerial appendage, that Stigmaria is always in the position of a root; and seeing that all the other fragments referred to have precisely the same characteristics of form and structure as those roots, we have the strongest *a priori* ground for believing that they too were roots; anyhow, until the opposite view is demonstrated to be probable by more conclusive evidence than has yet been discovered, deductive reasoning from what we do know to be facts compels us to infer that *true* Stigmaria were *always* roots.



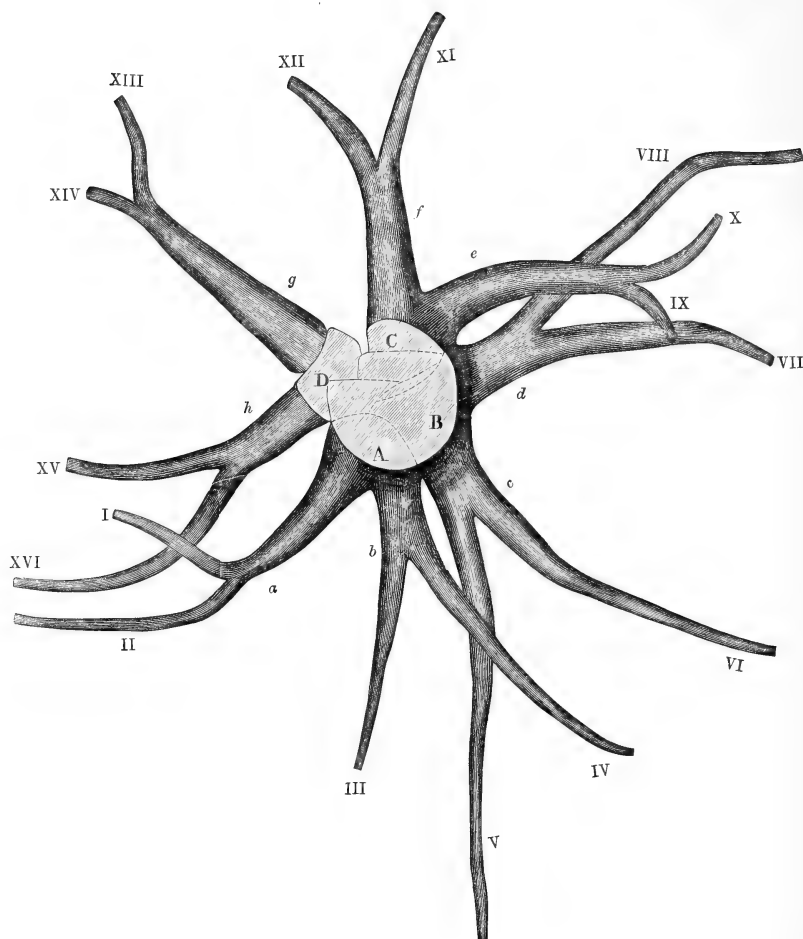
## A P P E N D I X.

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SINCE the preceding pages were put into type, probably the finest example of a fully developed *Stigmaria ficoides* yet seen has been discovered and has come into my possession. Mr. Murgatroyd, the intelligent proprietor of a large quarry of Carboniferous Sandstone at Clayton near Bradford, in Yorkshire, removing some stone by means of dynamite, found amongst the exploded materials some fragments of a *Stigmaria*. Seeing that the root extended into the undisturbed rock, with a thoughtfulness highly creditable to him, he ceased to employ explosive materials, and had the overlying stratum removed with great care. The result was the revealing of the magnificent specimen represented in Plate XV. This representation is a copy of a beautiful photograph taken by Mr. R. C. Clifford, a skilful young professional photographer, residing at Westgate, Bradford, to whom I am indebted for permission to use the photograph in illustration of this memoir. The photograph has been reproduced by the Automatic Engraving Company, of Willesden Green, near London. The tree stands upon a flat stratified surface, composed of an arenaceous shaly bed, which is abundantly permeated by the remains of its disorganised rootlets, and upon which its magnificent roots are spread out with undisturbed regularity. The overlying stratum is a hard sandstone, identical with the inorganic material of which the roots themselves consist. It is obvious that the entire base of the tree became encased in a plastic material, which was firmly moulded upon these roots whilst the latter retained their organisation sufficiently unaltered to enable them to resist all superincumbent pressure. This external mould then hardened firmly, and as the organic materials decayed they were floated out by water which entered the branching cavity; at a still later period the same water was instrumental in replacing the carbonaceous elements by the sand of which the entire structure now consists. It is obvious that we have not got the ultimate divisions of the roots in their entire length. Their extremities have failed to be preserved, from a reason given at p. 29. Still the roots, as seen in the plate, extend 29 feet 6 inches from right to left, and 28 feet in the opposite direction.

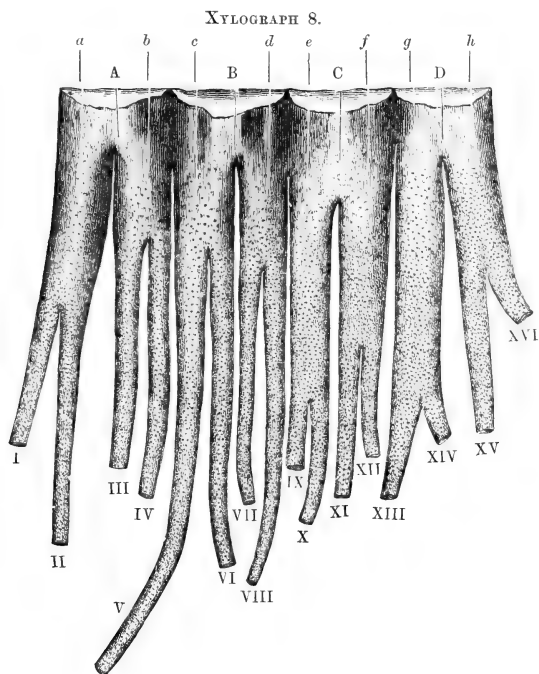
## STIGMARIA FICOIDES.

XYLOGRAPH 7.



The above xylograph represents accurately the arrangement of these roots as seen from above; it is reduced from a large plan carefully prepared by Chas. Brownridge, F.G.S., for Mr. Adamson, F.G.S., the Secretary of the Geological Society of Leeds, who has kindly allowed the above reduced figure to be copied from it by photography. As the preceding pages have shown to be almost invariably the case, four large primary roots, A, B, C, and D, radiate from a large

central mass which projects about 4 feet above the plane upon which the roots are outspread, and the top of which has a transverse mean diameter of 4 feet 4 inches, equal to a circumference of 13 feet. The specimen confirms the statement made in a previous part of this memoir (see page 16) that these Stigmarian roots normally dichotomised but twice. The following xylograph is a diagrammatic representation in which I have placed the four roots, A, B, C, and D, with their respective branches, side by side, for the purpose of showing accurately their relative lengths and the varying positions of their dichotomies. Their several diameters are not represented.



The following table gives the length of each division of the several roots between these dichotomies.<sup>1</sup>

Length of each of the four undivided roots from the edge of the transverse section of the stem to the first dichotomisation.

A. 1 foot 4 inches

C. 1 foot 8 inches

B. 1 „ 4 „

D. 1 „ 5 „

<sup>1</sup> The Roman numerals attached to each of the XVI terminal branches of these roots are also attached to the same branches on Plate XV.

Length of each of the branches between the first and the second dichotomies.

<i>a.</i> 5 feet	<i>e.</i> 6 feet
<i>b.</i> 3 „ 11 inches	<i>f.</i> 4 „ 3 inches
<i>c.</i> 3 „ 10 „	<i>g.</i> 7 „ 3 „
<i>d.</i> 4 „ 4 „	<i>h.</i> 3 „ 6 „

Length of each of the terminal undivided branches.

I. 4 feet	IX. 2 feet
II. 7 „	X. 3 „ 6 inches
III. 6 „ 6 inches	XI. 4 „ 6 „
IV. 7 „ 8 „	XII. 3 „ 3 „
V. 12 „ 8 „	XIII. 3 „
VI. 9 „	XIV. 1 „ 2 „
VII. 7 „	XV. 4 „ 6 „
VIII. 9 „ 5 „	XVI. <sup>1</sup> 2 „

We do not know the full length of V, for it disappeared in a hard face of the quarry, which, being under a roadway, could not easily be followed.

Interpreting this specimen as I have explained Fig. 2 (Plate I), aided by the light thrown upon both by the Figures 5 and 6 (Plate III), I conclude we have here no part of the true aerial stem, which seems to have died down to its own base and disappeared. The central mass consists solely of the coalesced proximal ends of the four primary roots. In this specimen the absence of every trace, either of rhizomatous features, or of additional aerial stems ascending from these roots is also conspicuous.

In each of the four roots the rootlet-scars are distinctly seen covering the eight secondary branches *a*, *b*, &c. The ultimate divisions show them in the normal form so characteristic of *Stigmaria*. How little the ramifications of this *Stigmaria* have in common with the diagram published by M. Renault<sup>2</sup> need not be dwelt upon.

Still more recently a second and somewhat larger example has been discovered in the adjoining Fall-Top Quarry, belonging to Messrs. Briggs and Shepherd, not much above a hundred yards from, and resting upon the same shaly bed, as that just described. The two specimens correspond in every essential detail, only that several of the large roots in the Fall-Top fossil have not yet been relieved of the thick mass of sandstone by which they are overlain. The following measurements are taken in the same way as those on the preceding page :

<sup>1</sup> Since the xylograph 8 was prepared I have succeeded in laying this branch (xvi) bare, and tracing its length to a distance of seven feet, when it became completely flattened, so that its upper and lower surfaces were almost in contact. The additional length thus revealed is correctly represented in xylograph 7.

<sup>2</sup> 'Cours de Botanique fossile,' Première année, pl. 19, fig. 9.

- A. Two feet 3 inches.  
 B. *Nil*. The cleft separating this root into its two primary divisions reaching the upper surface of the central mass.  
 C. Two feet.  
 D. Two feet 2 inches.

From the first to the second dichotomy.

<i>a.</i> 5 feet 6 inches	<i>e.</i> 6 feet
<i>b.</i> 7 "	<i>f.</i> 4 " 3 inches
<i>c.</i> 6 " 6 inches	<i>g.</i> 6 "
<i>d.</i> 7 "	<i>h.</i> 5 " 3 "

From the second dichotomy to the uncovered end of each root.

I. 14 feet	IX. None uncovered
II. 14 " 6 inches	X. Ditto
III. 22 "	XI. Ditto
IV. 7 " 6 "	XII. Ditto
V. 8 "	XIII. Ditto
VI. 6 " 6 "	XIV. Ditto
VII. } But a few inches	XV. Ditto
VIII. }	XVI. Ditto

Whilst, as this table shows, the prolongations of ten of the ultimate root-branches were hidden by the rock into which they plunge, No. III shows what may be expected of them whenever they are uncovered. This root ran in a direction more favorable for exploration. I followed it therefore until 22 feet were uncovered—which, with the addition of the other two segments, made a total length of 31 feet 3 inches from the exterior of the base of the central stem, and even this did not give us its entire length. Where we ceased to follow it the root was so completely flattened, that whilst its breadth was 4 inches its maximum thickness was only  $\frac{1}{4}$ ths of an inch. Hence, in its uncompressed state, this root can scarcely have exceeded  $2\frac{1}{2}$  inches in diameter. How much farther it extended in length we have not yet ascertained.<sup>1</sup>

<sup>1</sup> This root has since been traced to its termination, its entire length being 37 feet 4 inches. It continued to be completely flattened to its apex, which also narrowed to a point. This specimen throws light upon what has taken place in at least many of these root-terminations. After the vegetable elements had floated out, as described at p. 25, some obstruction prevented the inorganic sand, by which the cavity left by the disappearance of the organic material was filled, from reaching the extremities of these narrowing tunnels. Thus deprived of all internal support, instead of retaining their cylindrical form these cavities were crushed down by the weight of the superimposed mud and sand, roof and floor being thus brought into close contact. In many cases all traces of these terminations have ultimately disappeared.

Careful measurements of the circumference of each of the four primary roots of this specimen gave the following results :

A. 7 feet 6 inches

C. 8 feet 8 inches

B. 8 „ 6 „

D. 7 „ 6 „

We thus see that we have traced the gradual diminution of these roots from a mean diameter of about 32 inches to one of  $2\frac{1}{2}$  inches, which, as we have already seen, was not the limit of the reduction.<sup>1</sup> Such a diminution, combined with the fact that no trace of aerial shoots presented themselves in either of these superb specimens, is absolutely conclusive against the hypothesis that these roots are rhizomes.

In both these examples a thin film of carbonaceous matter invested them throughout all their ramifications. They had evidently been huge and isolated trees growing upon the same horizontal plain, and not portions of a dense forest. To this circumstance, probably, was due the fact that they were not planted upon a bed of coal; any little vegetable soil that accumulated under their localised shade would attain to no thickness, and would readily be removed by denudation.

I am indebted to my friend J. W. Davis, Esq., F.G.S., of Halifax, for the following sections, showing the geological horizon to which these trees belong. At p. iv of my "Introduction" I have given, also on the authority of Mr. Davis, a section of the beds between the Elland Flagstones and the "Rough Rock" or Millstone Grit. The present section shows the upward continuation of the same series of beds, with a few observations in reference to them.

Clifton or Oakenshaw Rock	. . . 80 0	Shales (with 80 yards Band Coal)	. . . 180 0
Shales with Stone and Coal	. . . 70 0	Hard-bed Band Coal	. . . 1 2
Crow Coal with partings	. . . 7 6	Shales (with 36 yards Band Coal)	. . . 137 0
Shales with Ironstone (Low Moor)	. . . 36 0	Hard-bed Coal (Ganister)	. . . 2 2
Black-bed Coal	. . . 2 6	Shale, &c.	. . . 29 6
Measures	. . . 180 0	Middle Band or Clay Coal	. . . 0 6
Better-bed Coal	. . . 1 6	Stone and Shale	. . . 62 0
Shales	. . . 54 0	Soft-bed Coal	. . . 1 6
Elland Flagstone— <i>a.</i> Flags	. . . 30 0	Shales	. . . 102 0
<i>b.</i> Shale	. . . 35 0	Coal and Seat Earth	. . . 5 6
<i>c.</i> Flags	. 120 to 180 0	Rough Rock	. . . . .

"The Elland Flag rock is of great thickness, and forms a bold range of hills from Sheffield and Wadsley, northwards to Penistone, west of Huddersfield, south and east of Halifax to north of Leeds. In Lancashire it is the Rochdale and Upholland Flags; probably when deposited it covered an area of 1500 square miles, and it is the thickest and most persistent of the Coal Measures sandstones.

<sup>1</sup> The note on the previous page shows that the root terminated in an absolute point.

“In the neighbourhood of Halifax, at South Ofram, it is 150 feet thick ; thence it tops the hills at North Ofram, and at Queensbury and Clayton is still thicker. It is divided by a bed of shale at these places ; the best sandstone and flags are at the bottom, 160 to 180 feet thick, then 35 feet of shale, and above the shale about 30 feet of flags, sometimes poor and raggy.

“The trees at Clayton are from the shale and rag above the lower flagstone, which in this quarry is worked to a depth of 80 to 100 feet.”

I may only add in conclusion that the magnificent fossil described in the above pages is now at the Owens College at Manchester, in the Museum of which institution it will shortly be mounted in a manner worthy of its perfection.<sup>1</sup>

<sup>1</sup> In addition to the above specimens no less than seven similar examples, though of smaller size, have been discovered in excavating for the foundations of some buildings in Darley Street, Bradford. Though of smaller size, these new specimens, so far as they have been uncovered, lead to the same conclusions as those enunciated in the preceding pages.





## GLOSSARY OF BOTANICAL TERMS EMPLOYED IN THE MONOGRAPH.<sup>1</sup>

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ACROPETAL.—Where a growing shoot develops other lateral structures or organs in succession, behind the growing tip of the shoot.

BARRED TISSUES.—Consist of tracheids or vessels, the walls of which are thickened internally by transverse bars of woody material (lignine) which alternate with parallel thin spaces; modified scalariform vessels.

CAMBIFORM TISSUE.—Cellular tissue of the phloëm produced from the cambium, and which has assumed a permanent condition; phloem tissues the elements of which are similar in character to that of the cambium in their elongated form and thinness of walls. See De Bary, 'Phanerogams and Ferns,' Eng. Trans., p. 327.

CAMBIUM.—A thin zone of meristematic cells intermediate between the exterior of the exogenous vascular zone and the innermost surface of the bark, and capable of developing new structures from either or both of its surfaces. It also appears between the xylem and the phloem elements of isolated vascular bundles, *e. g.* foliar or rootlet bundles.

CAULINE.—Leaf-bearing axes.

CENTRIFUGAL OR EXOGENOUS VASCULAR CYLINDER.—A zone of vessels or tracheids surrounding the centripetal cylinder where the latter is present, and increasing in thickness by additions made to its *outer* border through the action of a circle of meristem cells known as *cambium*; its growth in thickness therefore proceeds from within outwards.

CENTRIPETAL VASCULAR CYLINDER.—A zone common to many Carboniferous Cryptogams, which, commencing as a medullary sheath, increases in size and thickness by a conversion of the medullary cells which it surrounds into vessels or tracheids. Its component elements are never arranged in radiating lines or *laminae*, and it is the source whence the fibro-vascular bundles going to the leaves are derived. Its growth, therefore, is centripetal.

<sup>1</sup> Introduced at the recommendation of the Editor for the use of geologists who may not be familiar with botanical terms.

**DICHOTOMY.**—An unvarying division of *single* organs into *two* more or less equal structures. A growing bud has an apical cell, or cluster of cells, which divide equally, giving rise to two dichotomous branches.

**DISTAL.**—The end of an organ most remote from the organism to which it is attached.

**EMERGENCES.**—Hair-like structures, which instead of being developed, like hairs, entirely from a single cell of the epidermis, also originate partly from some of the structures that underlie the epidermis.

**FIBRES.**—Prosenchymatous cells, whose walls are thickened by deposits of woody substance on their inner surfaces.

**FIBRO-VASCULAR BUNDLES.**—Strands compounded, when perfect, of vessels, tracheids, fibres and cells constituting the *xylem* part, and of vascular (sieve-tubes), cellular and fibrous elements, the *phloem* or *bast* portion of each bundle.

**FOLIAR BUNDLES.**—Fibro-vascular bundles primarily prolongations from the medullary sheath, or, in the case of the Carboniferous Cryptogams, from the centripetal vascular cylinder, and passing outwards through the cortex to the leaves.

**MEDULLA OR PITH.**—The central cellular axis of a stem or branch enclosed within a circle of vascular bundles.

**MEDULLARY CAVITY OR CANAL.**—A hollow space in the centre of the cellular medulla, formed either by the absorption of its central cells or by their rearrangement round the interior of the vascular cylinder, owing to the growth of the latter proceeding more rapidly than that of the medullary parenchyma does.

**MEDULLARY RAYS.**—Radial vertical plates of cells intervening between the laminae of the exogenous vascular cylinder, and connecting the medulla with the bark.

**PRIMARY MEDULLARY RAYS.**—Those first seen between the vascular bundles when a vascular zone or cylinder commences its formation, and in which the connections between the medulla and the cortex are direct and undisturbed.

**SECONDARY MEDULLARY RAYS.**—The vessels of the first formed vascular bundles which intervene between the primary medullary rays are usually few in number. As the cylinder which they originate grows in thickness, these bundles enlarge laterally as well as radially. The additions assume the form of laminae, which are elongated vertically, and arranged in radiating groups, which latter constitute the vascular *wedges* of transverse sections; the laminae of each of these wedges are in close contact at their inner extremities, but spread out at their outer ends in a fan-shaped manner. At the same time new vertical *cellular* laminae are intercalated, though but few of these reach the medulla at their inner ends. These latter cellular laminae are the *secondary* medullary rays.

**MEDULLARY SHEATH.**—*Étui médullaire* of Brongniart. The first formed ring of vascular bundles, separating the medulla internally from the outer zone of

cortex. This sheath is chiefly concerned in supplying the leaves with their first vascular bundles, and is the centripetal vascular cylinder of many Carboniferous stems.

MERISTEM.—Cells capable of multiplication by the formation of septa or walls crossing their inner cavities.

MONARCH, DIARCH, &c.—In a transverse section of a young root, the first-formed vessels appear at a variable number of points near the circumference of a central cellular cylinder. The vascular bundles of roots are called *Monarch* when there is but one such initial point. *Diarch* if two. *Triarch* if three, &c.

MONOPODIAL OR FALSE DICHOTOMY.—Where the apex of a growing shoot advances whilst any lateral branches, however near to the apex, arise from a place lower down than the true apex.

ORIENTATION.—The uprising of branches from some other organ, as of foliar bundles from the centripetal cylinder of a *Lepidodendron* or of rootlet bundles from the exogenous zone of *Stigmaria*.<sup>1</sup>

PARENCHYMA.—Cells whose length does not greatly exceed their breadth.

PERIDERM.—An external protective layer of the bark replacing the detached epiderm of young plants. It is usually a Phellem, *i. e.* cork.

PHELLEM.—A peripheral cork-layer of the bark developed centripetally from the exterior of the Phellogen.

PHELLODERM.—A cellular layer of the bark developed centrifugally from the inner side of the Phellogen.

PHELLOGEN.—A thin meristem cambium-layer in the cortex.

PHLOEM.—The bast portion of a fibro-vascular bundle characterised by the presence in it of sieve-tubes or their representatives, as the xylem or wood portion is characterised by the presence of vessels or Tracheids.

PHYLLOME.—A modified part of a plant primarily capable of developing into a leaf, *e. g.* each of the parts of a flower.

PROSENCHYMA.—Elongated, spindle-shaped cells with pointed or oblique ends.

PROXIMAL.—The end of an organ nearest to the centre of the organism to which it is attached.

QUINCUNCIAL.—A term applied to the arrangement of the rootlet-scars of *Stigmaria*, each one of which occupies the centre of a surrounding group of four similar ones.

RHIZOME.—A creeping subterranean stem, capable of giving off leaves or aerial shoots from its upper surface and from the ends of its branches, and roots from its lower surface.

ROOT.—A descending axis in contra-distinction from a stem or ascending axis.

<sup>1</sup> This definition of "Orientation" represents the meaning of the word as used in the Monograph, but differs from that assigned to it by the French botanists.

- ROOTLETS.—Secondary organs of *Stigmaria* performing root-functions, but having a different structure from the roots.
- ROOTLET BUNDLE.—A fibro-vascular bundle derived partly from the exogenous or centripetal vascular cylinder of the root, and partly from the cambiform or phloëm zone which immediately invests the exogenous cylinder.
- ROOTLET-BUNDLE CYLINDER.—A cylinder consisting of several layers of cells surrounding both the xylem and phloëm elements of the bundle in the rootlets of *Stigmaria*.
- ROOTLET-CORTEX.—The outer wall of each cylindrical rootlet of *Stigmaria*, an extension from the most external or parenchymatous layer of the root-bark.
- ROOTLET-CUSHION.—A solid cylinder of cellular tissue embedded in the meristemic zone of the root-bark, and transmitting the rootlet bundle through its centre.
- ROOTLET-SCARS.—Hollow depressions left on the outer surface of a *Stigmarian* root by the disappearance of the rootlets. The latter have been mechanically broken off, not being deciduous like a falling leaf.
- SCLEROUS TISSUE OR SCLERENCHYMA.—Cells or tubes of any kind of which the walls are uniformly thickened by woody deposits on their inner surfaces.
- TRACHEIDS.—Single elongated prosenchymatous cells, the ends of which have not been absorbed, which, when living, contained no protoplasm, and whose walls also are usually furnished with bordered pits.
- VEGETATIVE REPETITION.—Multiplications of any organ, each of which multiplied examples has typically the same structure and functions as those which it resembles.
- VESSELS.—Prolonged tubes, usually formed by the coalescence of linear series of cells, the divisions (septa) between the ends in mutual contact having been partially or entirely absorbed.

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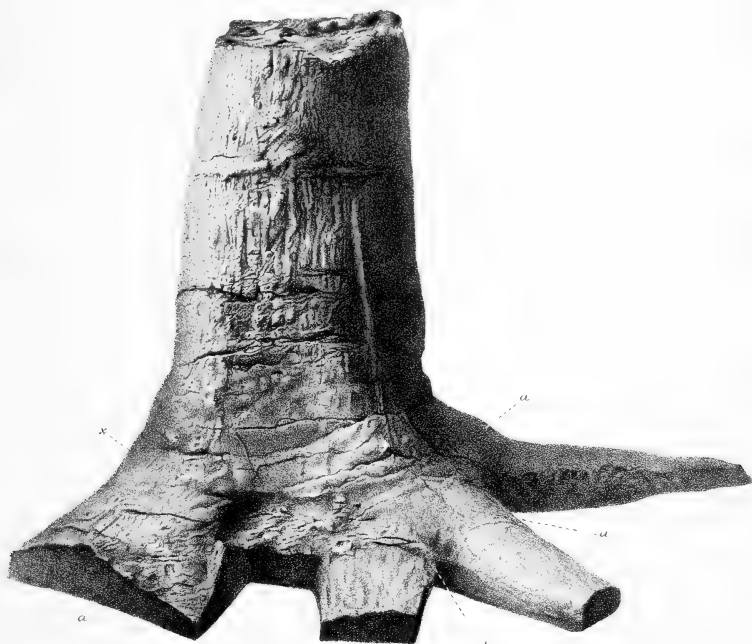


PLATE I.

Fig. 1.—Cast of one of the Stigmarian trees found at Dixon Fold. (Page 5.)

Fig. 2.—Cast of a second of the same group of trees. (Page 5.)

1



2





PLATE II.

Fig. 3.—Under surface of a Stigmarian root in the Museum of the Leeds Philosophical Society. (Page 5.)

Fig. 4.—Under surface of a Stigmarian root in the Museum of the College of Science, Leeds. (Page 6.)



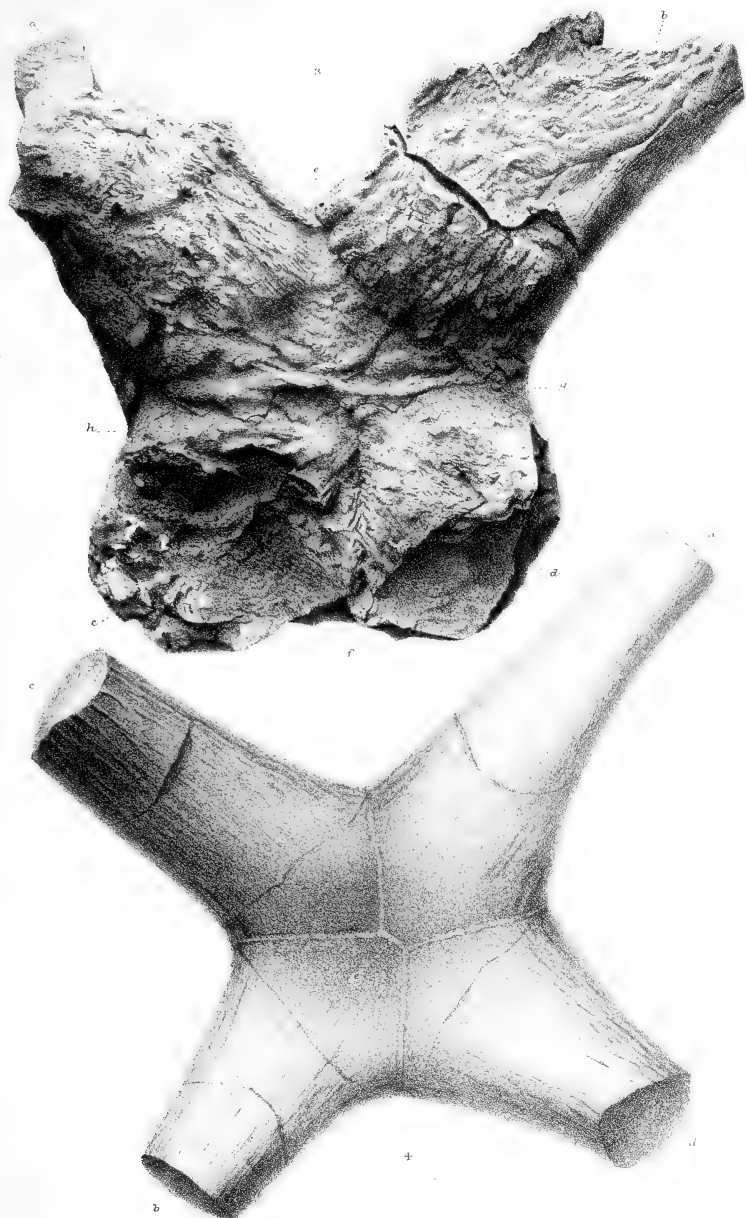






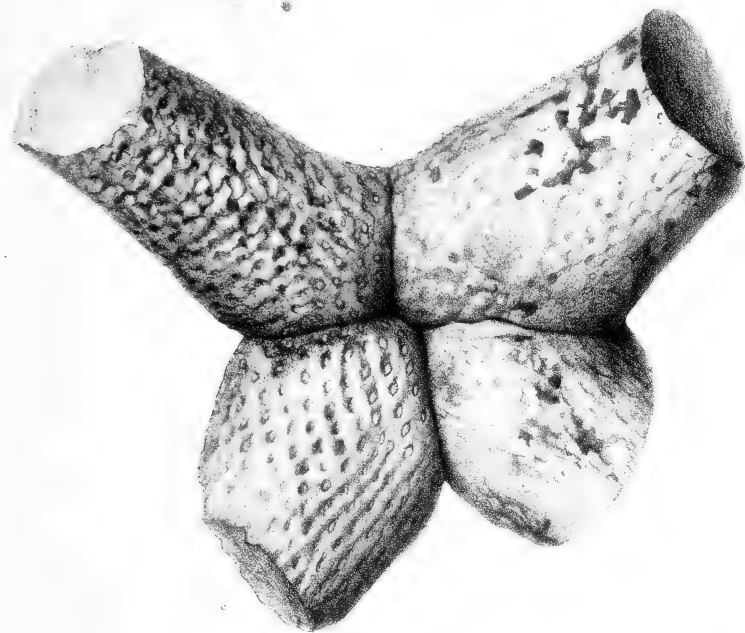
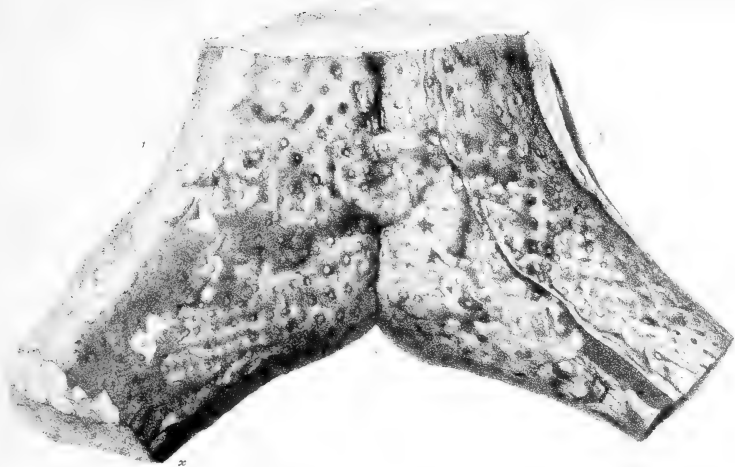
PLATE III.

Fig. 5.—Side view of a very young Stigmarian root. (Page 6.)

Fig. 6.—Under surface of Fig. 5. (Page 7.)

Fig. 6 *a*.—Six of the rootlet-scars from near Fig. 5 *a*. Nat. size. (Page 29.)

Fig. 6 *b*.—Six similar rootlet-scars from near the point *x* of Fig. 5. Nat. size.  
(Page 29.)







## PLATE IV.

Fig. 7.—Medullary angles of three vascular wedges from a transverse section of the vascular cylinder of a *Stigmara*. *a*. Medullary cells. *b*. Vascular wedges. *b'*. Elongated cells of primary medullary rays. *b''*. Secondary medullary rays.  $\times 90$ . Cabinet, No. 744. (Pages 10, 14.)

Fig. 17.—Part of a transverse section of a vascular cylinder, including a longitudinal section of a secondary medullary ray containing barred Tracheids. Two radial lines of vessels of the cylinder, *b*, *b*. Barred Tracheids, *b''*.  $\times 80$ . Cabinet, No. 767. (Page 15.)

Fig. 19.—Peripheral portion of the transverse section of the vascular cylinder, Fig. 14, Pl. VII, in which a new zone is being added exogenously. Older vessels of the cylinder, *b*. Imperfectly developed vessels, &c., of the newer zone, *b'*.  $\times 39$ . (Pages 17, 24, 32.)

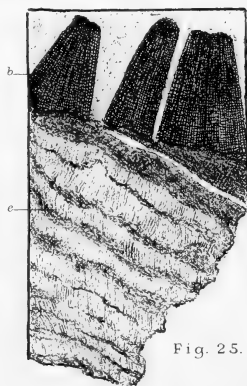
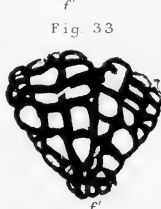
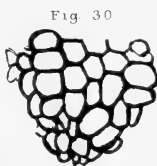
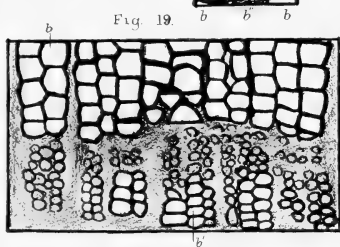
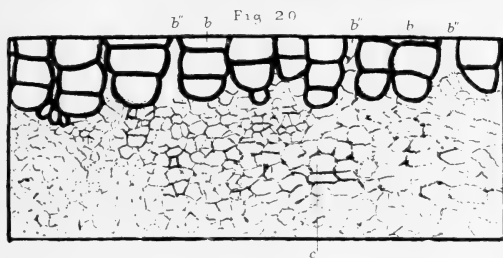
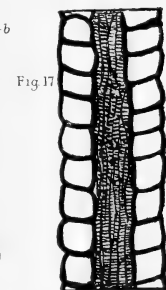
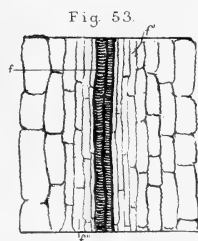
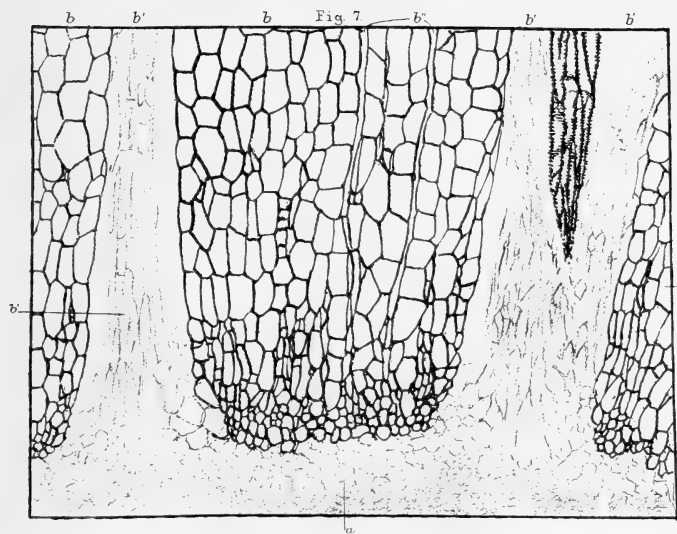
Fig. 20.—Periphery of a transverse section of a vascular cylinder with an investing cellular layer, which appears to be a cambium. Peripheral vessels of the vascular cylinder, *b*. Procambial cells, *c*.  $\times 75$ . Cabinet, No. 744. (Page 17.)

Fig. 25.—Transverse section of a fragment of *Stigmara* with a considerable development of the prosenchymatous zone, *e*, of figs. 22 and 23, Plate VIII.  $\times 3$ . Cabinet, No. 795. (Page 20.)

Figs. 28, 29, 30, 31, 32, 33.—Transverse sections of six rootlet bundles after they have escaped from the peripheral ends of the primary medullary rays, but before they have penetrated the cortex. In each of these, *f'* indicates the protoxylem of the wedge-shaped bundle and the broad opposite base of the wedge, including the small vessels, *f*, its latest additions.  $\times 80$ . Cabinet, No. 744. (Pages 23, 24, 26, 31.)

Fig. 53.—Small portion of the longitudinal section of a young rootlet bundle. Vascular bundle, *f*. Cells of the bundle sheath, *f'*, *f''*.  $\times 100$ . (Page 28.)









## PLATE V.

Fig. 8.—Tangential section from a vascular cylinder, showing transverse sections of the primary medullary rays, *b'*. Vascular rootlet bundles, *f'*.  $\times 5$ . Cabinet, No. 771. (Pages 13, 14, 34, 35.)

Fig. 13.—Transverse section of the primary medullary ray, Plate IX, fig. 12, but made close to the cortical surface of the vascular cylinder, *b*. Vascular rootlet bundle, *f*. First formed portion of the rootlet bundle, *f'*. Secondary medullary rays, *d*.  $\times 30$ . Cabinet, No. 856. (Pages 14, 23.)

Fig. 16.—Transverse section of a young primary medullary ray. Vessels of the xylem cylinder, *b'*. Cells of the medullary ray, *b*. Primary vessels of the rootlet bundle, *f'*. Later formed vessels, *f*. Secondary medullary rays, *d*.  $\times 14$ . Cabinet, No. 824. (Pages 14, 23, 31.)

Fig. 16A.—Transverse section of the vascular cylinder of a very young *Stigmara*. Cabinet, No. 773.  $\times 5$ . (Page 15.)

Fig. 46.—Transverse section of a rootlet cushion below the base of a rootlet. Vascular rootlet bundle, *f*. Small cells of the rootlet cushion, *h*. Zone of large cells investing the rootlet cushion, *h'*.  $\times 20$ . (Pages 26, 28.)

Fig. 47.—Similar section to 46, only partly invested by some of the tissues of the root-cortex. Small cells of the rootlet cushion, *h*. Investing zone of larger cells, *h'*. Prosenchymatous cells of the root-bark seen in tangential section, *e*.  $\times 20$ . Cabinet, No. 807. (Pages 26, 28.)

Fig. 48.—Central portion of Fig. 47, further enlarged. Rootlet bundle, *f*. Phloem portion of the bundle, *f'*. Cellular investment of the bundle, *f'''*.  $\times 200$ . (Pages 26, 28, 32.)

Fig. 49.—Some of the prosenchymatous cells of Fig. 47, *e*, undergoing fission by horizontal septa.  $\times 40$ . (Page 20.)

Fig. 46

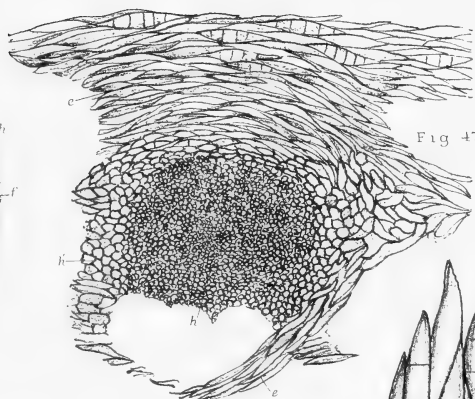
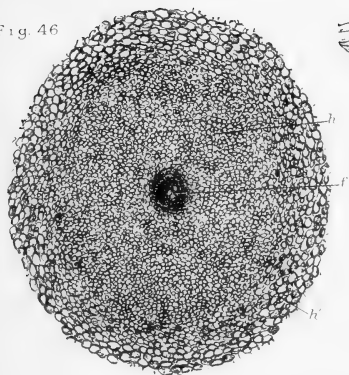


Fig. 47

Fig. 16

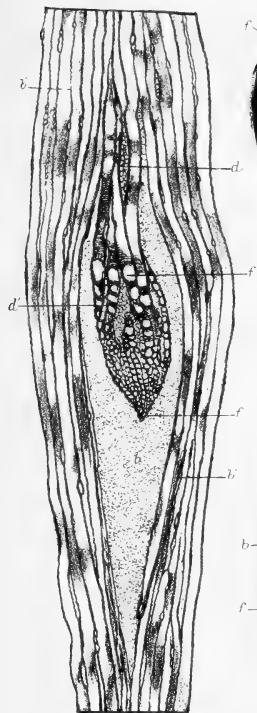


Fig. 16

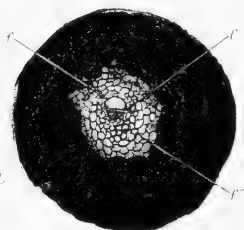


Fig. 16 A

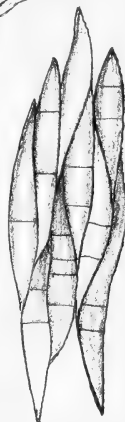


Fig. 49

Fig. 13

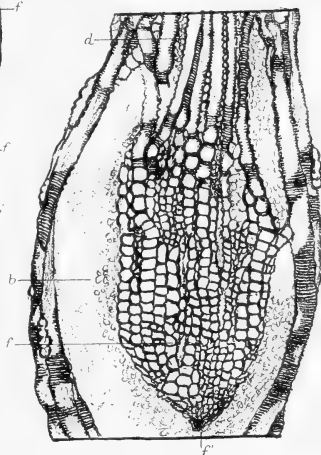
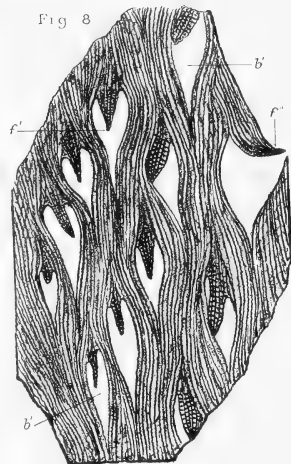


Fig. 8







## PLATE VI.

Fig. 9.—Longitudinal section through a young root of a *Stigmaria*. Medullary cavity, *a*. Vascular cylinder, *b, b*. Vessels of the cylinder deflected to form a rootlet bundle, *f*, passing out through a primary medullary ray, *b'*. Secondary medullary rays, *b'''*. Cortex parenchyma, *d*. Cortex meristem, *d'*. Base of rootlet, *g*. Rootlet cushion, *h*.  $\times 10$ . Cabinet, No. 776. (Pages 14, 18, 19, 20, 22, 31, 34, 35.)

Fig. 45.—Longitudinal section of the proximal end of another rootlet. Parenchymatous zone of the root-bark, *d*. Prosenchymatous zone of the root-bark, *d'*. Rootlet bundle, *f*, enclosed within its rootlet bundle-sheath, *f''*, and passing outwards through the rootlet cushion, *h, h'*. Apex of the rootlet cushion, *h'*. Outer cortical zone of the rootlet, *g*.  $\times 18$ . (Pages 19, 26, 27.)



Fig 45

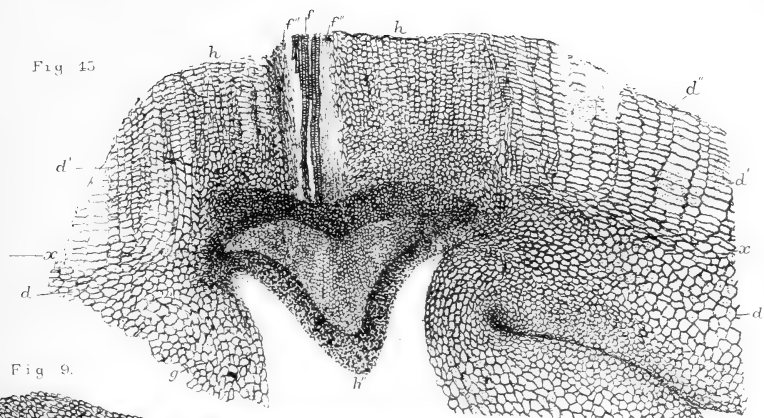
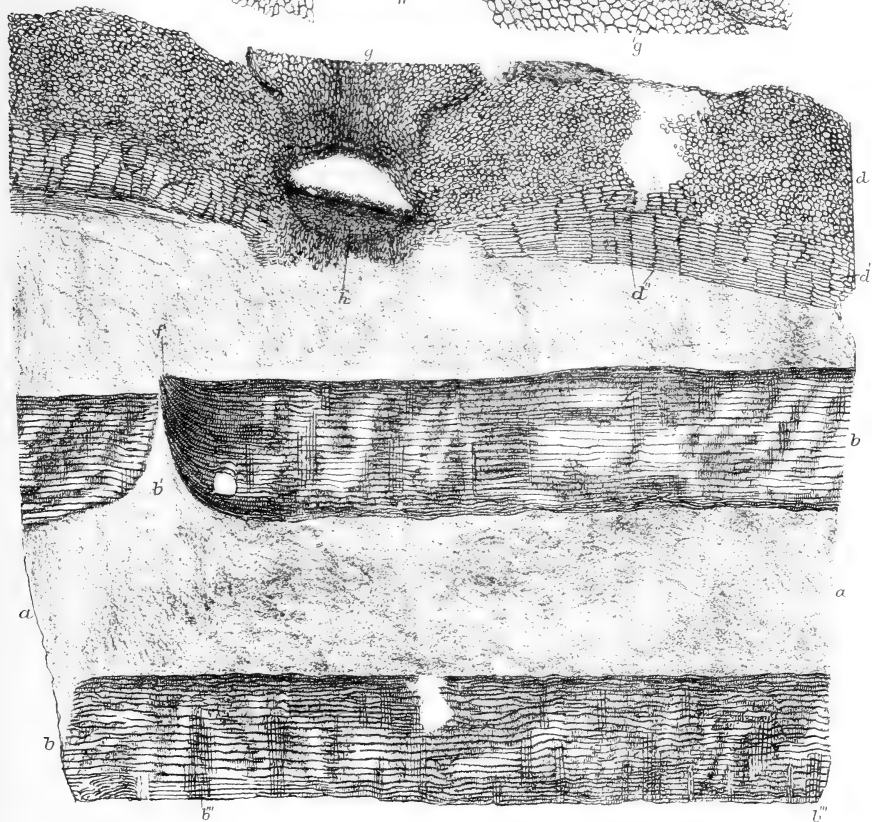


Fig 9.







## PLATE VII.

Fig. 10.—A radial section through the outermost vessels, *b*, of the vascular cylinder. Cambiform zone, *c*. Cells belonging to a more external cortical parenchyma, *d*, *d*.  $\times 90$ . Cabinet, No. 779 (Pages 13, 17, 18.)

Fig. 11.—A tangential section through a portion of a vascular cylinder. Xylem laminae, *b*. Secondary medullary rays, *b'*. Rootlet bundles, *f*.  $\times 5$ . Cabinet, No. 771. (Pages 11, 13, 15.)

Fig. 14.—Transverse section of a medium-sized vascular cylinder. Medullary cavity, *a*, containing an intruded Stigmarian rootlet, *g*. Vascular wedges, *b*. Primary medullary rays, *b'*. Obliquely longitudinal sections of rootlet bundles, normally co-extensive with the entire thickness of the cylinder, *f*. Section of a rootlet bundle escaping from the cylinder, *f'*.  $\times 5$ . (Pages 13, 14, 17, 23, 25, 33, 35.)

Fig. 26.—A portion of Fig. 25, further enlarged. External pressure has disturbed the transversely intersected prosenchymatous cells along the lines, *e'*, *e'*.  $\times 18$ . (Page 20.)

Fig 14

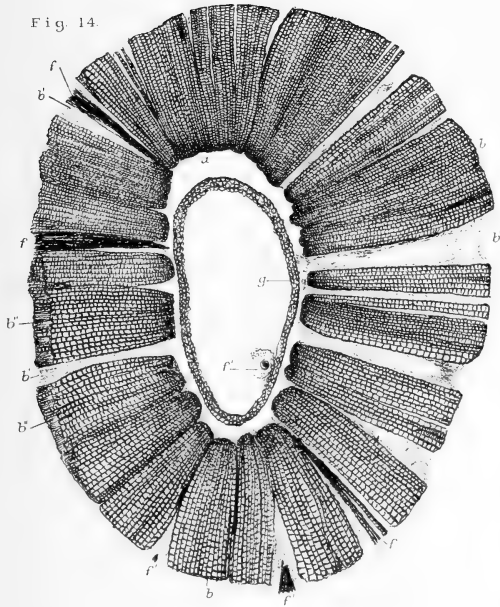


Fig 10

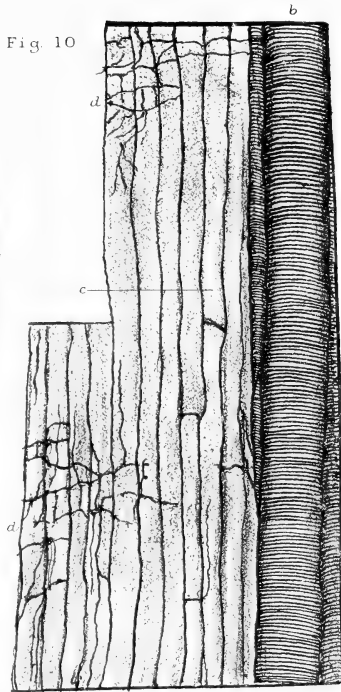


Fig 26

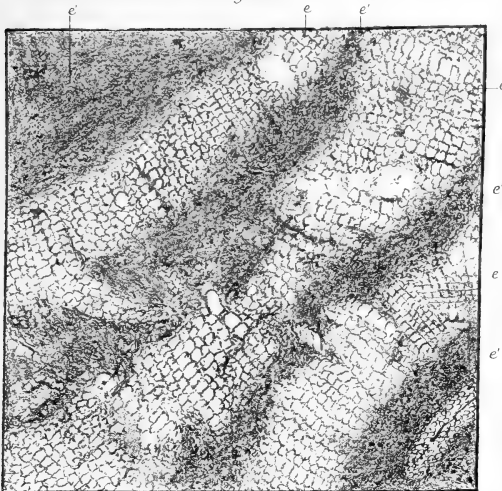
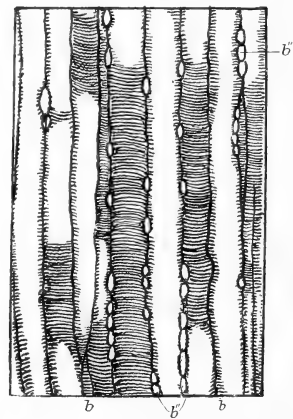


Fig 11.







## PLATE VIII.

Fig. 15.—Transverse section of a vascular cylinder with its more external cortical layer and the bases of three rootlets. Medullary cavity, *a*. Wedges of the vascular cylinder, *b*. Outermost cortical parenchyma, *d*. Meristem zone of bark, *d'*. Cortical prosenchyma, *e*. Rootlet bundle, *f*. Rootlet bundle cylinder, *f''*. Cortical zone of rootlet, *g*. Rootlet cushion, *h*.  $\times 6\frac{1}{2}$ . Cabinet, No. 759. (Pages 14, 18, 26.)

Fig. 22.—Outer cortex of a transverse section from the same specimen as Fig. 15. Outermost parenchyma, *d*. Meristem or bark cambium zone, *d'*. Prosenchymatous zone, *e*.  $\times 18$ . Cabinet, No. 757. (Pages 19, 20, 21, 43.)

Fig. 23.—Transverse sections of the cortex of a much older Stigmarian root than Fig. 22. Outermost cortical parenchyma, *d*. Meristem zone, *d'*. Cell walls of mother cells? *d''*. Prosenchymatous zone, *e*.  $\times 18$ . (Pages 19, 20, 21, 43.)

Fig. 24.—Tangential section through the meristem tissue, *d'*, of Fig. 23. Boundaries of mother-cells, identical with those of *d''* of Fig. 23.  $\times 9$ . (Page 20.)

Fig. 24A.—Tangential section of the tissue, *e*, of Fig. 23.  $\times 9$ . (Pages 20, 21.)



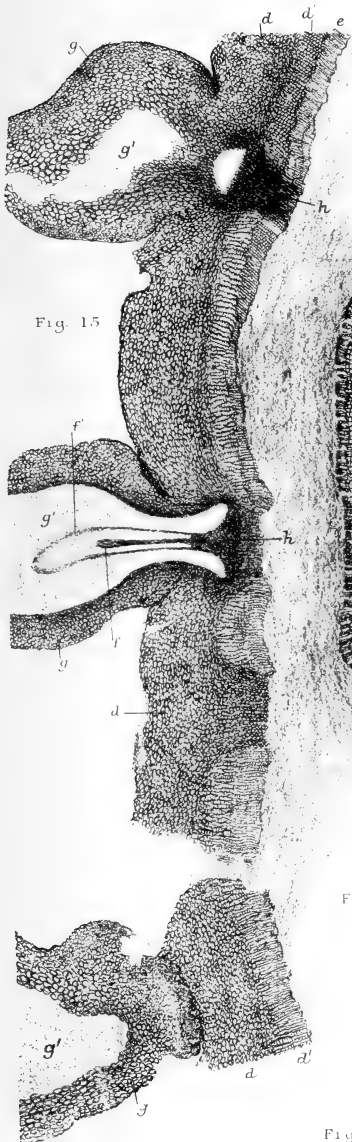


Fig. 15

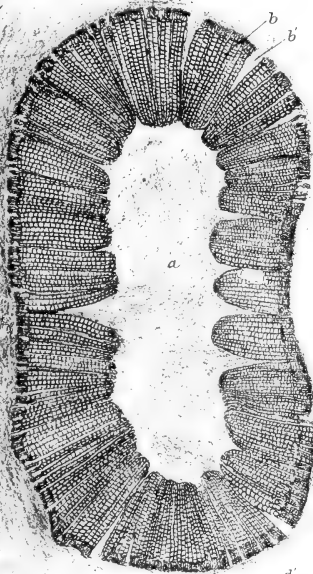


Fig. 22.

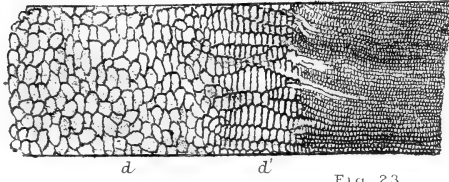


Fig. 23.

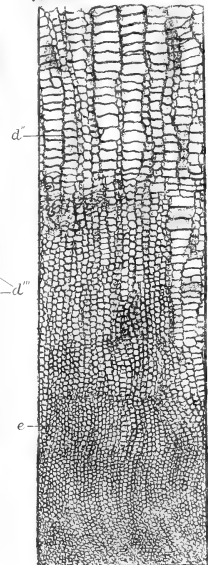
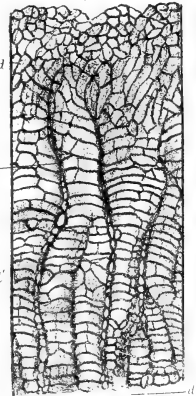


Fig. 24

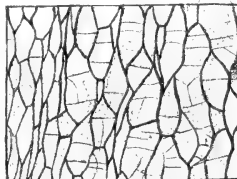
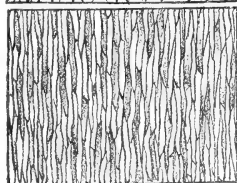


Fig. 24A







## PLATE IX.

Fig. 12.—Tangential section of part of a xylem cylinder, made close to the medulla, giving a transverse section of a primary medullary ray, *b*, and the vascular rootlet bundle, *f*, *f'*. Enlarged secondary medullary rays at the orientation of the younger part of the rootlet bundle, *d*.  $\times 30$ . Cabinet, No. 851. (Pages 14, 23.)

Fig. 18.—Transverse section of an extremely young root of *Stigmara*. Vascular wedges of the disturbed vascular cylinder, *b*. Superficial parenchyma of the cortex, *d*. Cortical prosenchyma, *d'*. Rootlets belonging to the root, *g*, *g*.  $\times 11$ . Cabinet, No. 775. (Pages 15, 18, 42.)

Fig. 34.—Another section like figs. 28—33, Plate IV, but with all its newest small vessels derived from a half-developed exogenous zone like Fig. 19, *b'*, Pl. IV.  $\times 80$ . (Page 23.)

Fig. 35.—A wedge-shaped rootlet bundle from the same position as the preceding ones, but from the exterior of the large vascular cylinder from Staffordshire. Protoxylem vessels, *f''*.  $\times 80$ . Cabinet, No. 750. (Pages 23, 24.)

Fig. 51.—Transverse section of a rootlet made about half way up the conical portion, *h'*, of the rootlet cushion. The outermost parenchyma of the root-bark, *d*. The cortical layer of the rootlet, *g*. The second cellular layer of the rootlet very rarely preserved, *g'*. Section of the small cells of the rootlet cushion, *h''*. Rootlet bundle and its sheath, *f*.  $\times 50$ . Cabinet, No. 821. (Page 27.)

Fig. 52.—Centre of Fig. 51. Xylem portion of the rootlet bundle, *f*. Phloem area of the bundle, *f'*. Bundle sheath, *f''*.  $\times 440$ . (Pages 28, 32.)

Fig 34.



Fig 35.

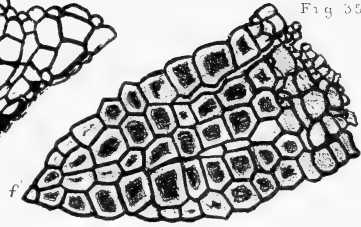


Fig 18.



Fig. 12.

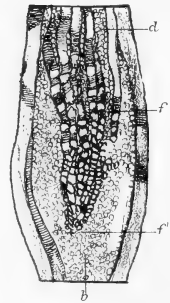


Fig 51.

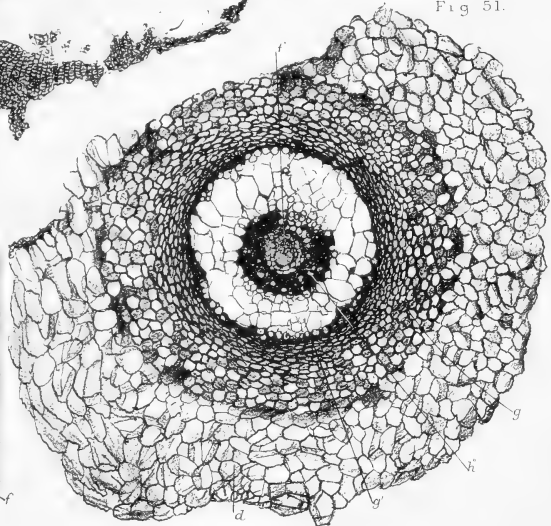
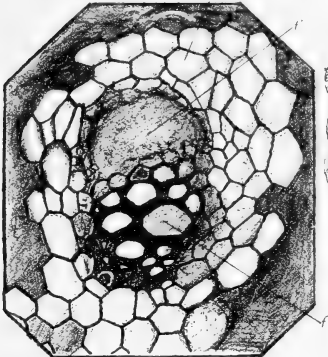


Fig 52.







## PLATE X.

Fig. 21.—Transverse section of the bark of Fig. 18, Pl. IX. Outer parenchyma, *d*. Prosenchymatous zone, *d'*.  $\times 18$ . Cabinet, No. 775. (Pages 18, 19.)

Fig. 42.—Transverse section of a large Stigmarian rootlet, *g*, into the interior of which several other younger rootlets have penetrated. Vascular bundle of the large rootlet, *f*. Cortex of one of the smaller rootlets, *g''*. Its inner vacant cavity, *g'*. Its vascular bundle and sheath, *f'*.  $\times 11$ . Cabinet, No. 848. (Pages 13, 25, 26, 33.)

Fig. 43.—Longitudinal section of the proximal end of a rootlet. Parenchymatous cortex of the root, *d*, *d*. Prosenchymatous cortex of the root, *e*. Vascular rootlet bundle, *f*, *f*. Rootlet bundle-sheath, *f'*. Branching cells investing the extremity of the rootlet cushion, *i*, *i*. Outer cortex of the rootlet, *g*, *g*. Fistular interior of the rootlet, *g'*.  $\times 18$ . (Pages 26, 27, 28.)

Fig. 44.—Longitudinal section of the proximal end of another rootlet. Prosenchymatous zone of the root-bark, *d'*. Central portion of the rootlet cushion, *h*, *h*. Conical extremity of the rootlet cushion inside the rootlet, *h'*. Rootlet bundle, *f*. Rootlet bundle-sheath, *f'*. Outer cortex of the rootlet, *g*. Fistular interior of the rootlet, *g'*.  $\times 18$ . Cabinet, No. 819. (Pages 26, 27, 28, 39.)

Fig. 50.—Minute branching tubular cells investing the surface of the conical extremity, *h'*, of the rootlet cushion, seen in the longitudinal rootlet sections, *e.g.* fig. 43, *i*, Pl. X. (Page 27.)



Fig. 43.

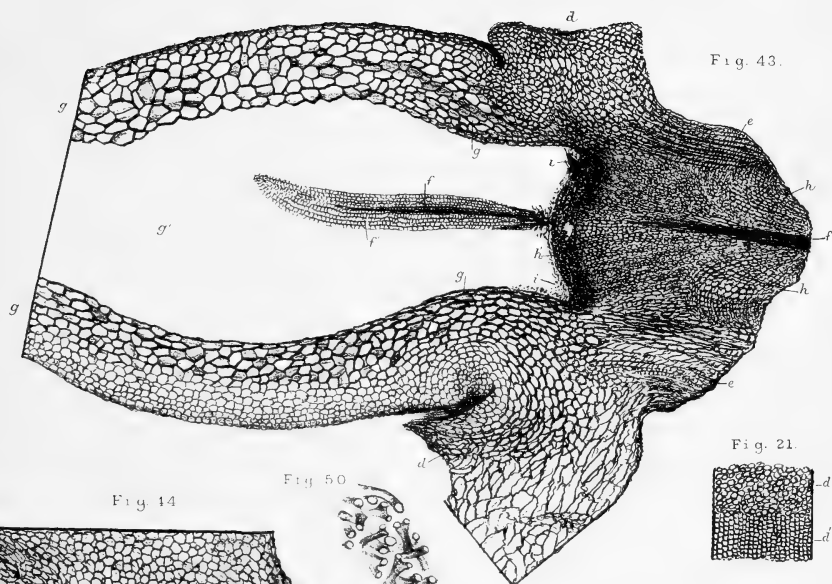


Fig. 21

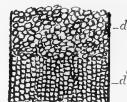


Fig. 14

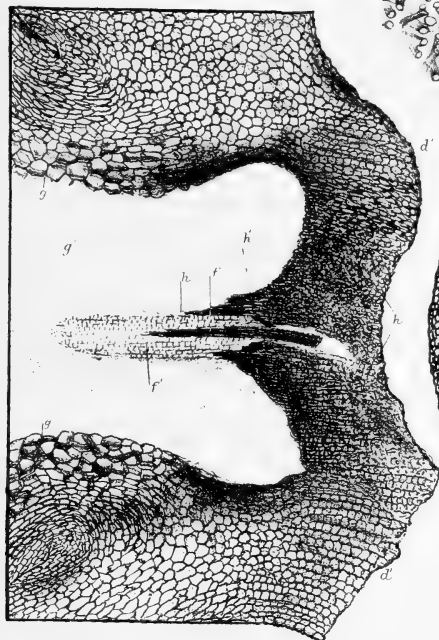


Fig. 50

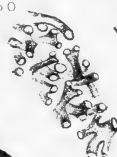
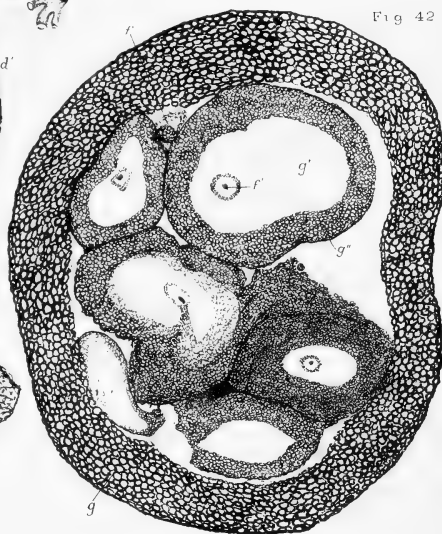


Fig. 42







## PLATE XI.

Fig. 36.—A second wedge-shaped rootlet bundle, like fig. 35, Pl. IX, from the exterior of the large vascular cylinder from Staffordshire. Protoxylem vessels,  $f'$ .  $\times 80$ . Cabinet, No. 750. (Pages 23, 24, 34.)

Fig. 54.—Transverse section of the rootlet bundle with its bundle cylinder, of a very young rootlet. Very small Tracheids at the point of departure of the monarch rootlet bundle,  $f, f''$ . Bundle cylinder,  $f'$ .  $\times 100$ . Cabinet, No. 831. (Page 29.)

Fig. 55.—A second rootlet bundle, like Fig. 54.  $\times 100$ . Cabinet, No. 829. (Pages 29, 31.)

Fig. 56.—A third, more advanced, rootlet bundle, like Fig. 54.  $\times 100$ . Cabinet, No. 775. (Page 29.)

Fig. 57.—Vascular bundle,  $f$ , and part of the bundle cylinder,  $f''$ , of a larger and older rootlet. Point of departure of the monarch bundle,  $f'$ .  $\times 100$ . Cabinet, No. 836. (Pages 29, 31.)

Fig. 58.—Rootlet bundle,  $f$ , and its cylinder,  $f''$ , of a yet older rootlet.  $\times 100$ . (Pages 29, 31.)

Fig. 59.—Rootlet bundle,  $f$ , with part of its monarch initial vessels at  $f'$ , but with two others yet deeper amongst the cells of the bundle cylinder at  $f'''$ . (Page 29.)

Fig. 60.—Rootlet bundle, with part of its bundle cylinder,  $f''$ . The more recently added of the vessels of the bundle,  $f$ , radiate from the monarch point of departure at  $\times 100$ . (Pages 29, 30.)

Fig. 61.—A second rootlet bundle, like Fig. 60, with its initial vessels at  $f'$ , and a small portion of its cylinder at  $f''$ . Here again the vessels of the older part of the bundle are non-radial; the younger additions are disposed radially.  $\times 100$ . Cabinet, No. 651. (Pages 29, 30, 34.)

Fig. 62.—Transverse section of a very young bundle,  $f$ , with its phloem elements preserved at  $f'''$ . Bundle cylinder,  $f''$ . (Page 32.)

Fig. 63.—Transverse section of a rootlet about to dichotomise. Inner border of the cortical zone of the rootlet,  $g$ . Fistular cavity of the rootlet,  $g'$ . Two bundles,  $f, f$ , each surrounded by its bundle-sheath or cylinder,  $f', f'$ , resulting from the division of one single bundle.  $\times 75$ . Cabinet, No. 862. (Page 32.)

Fig 55.

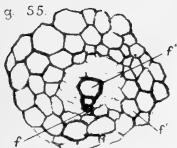


Fig 61.

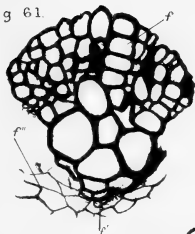


Fig. 56.

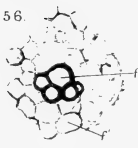


Fig. 54.

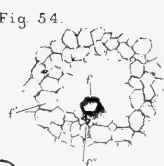


Fig 57.



Fig 58.

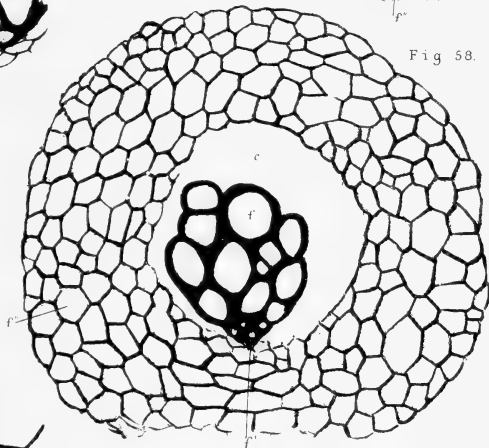


Fig 62

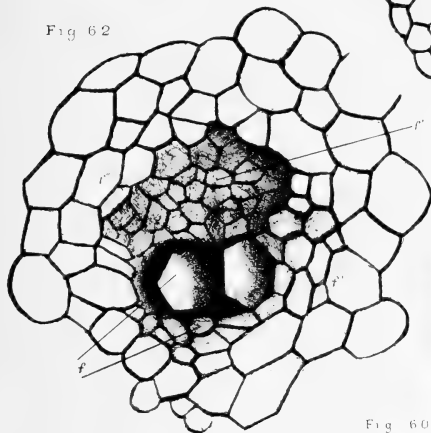


Fig 63

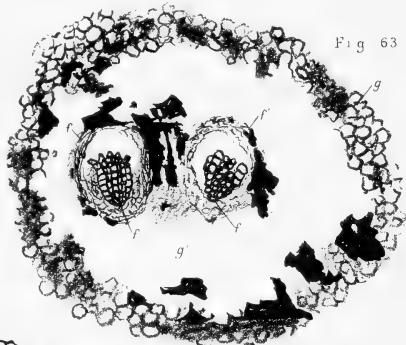


Fig 60

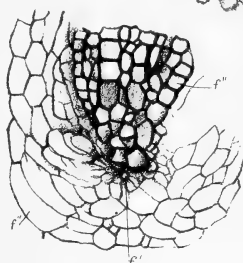


Fig 59

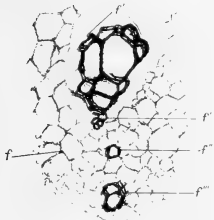
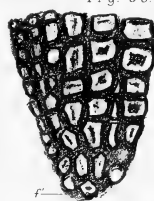


Fig. 36.







## PLATE XII.

Fig. 37.—Part of a fragment of a Stigmarian root split vertically. Exterior of the vascular cylinder, *b*. Rootlet bundles crossing the cortical region, *f*. Exterior surface of the cortex, *d*, *d*. Half the natural size. (Page 24.)

Fig. 38.—One extremity of Fig. 39, *b*. Vascular wedges, *b*, of the cylinder separated by primary medullary rays, *b'*. The central medullary cavity is occupied by an intruded Stigmarian rootlet, in the interior of which the rootlet bundle is preserved. Nat. size. Cabinet, No. 867. (Page 24.)

Fig. 39.—Side view of Fig. 38, with numerous rootlet bundles, *f*, enclosed within their several bundle sheaths, issuing from the primary medullary rays of the cylinder. Nat. size. Cabinet, No. 867. (Pages 24, 26.)

Fig. 40.—Fragment of a large nodule enclosing a disorganised Stigmarian root, almost identical with one of which the specimen, Figs. 38, 39, is the vascular cylinder. *d* represents a cast of the outer surface of one side of the root, with casts of the basal ends of the rootlets penetrating the stone. Rootlets from the opposite side of the root are seen at *g*, *g*, with their free ends pointing to the right. *f*, a mass of rootlet bundles resembling those given off from the exterior of Fig. 39. (Pages 24, 39.)

Fig. 41.—Inner surface of a fragment of the outermost bark, with rootlet bundles penetrating it to reach the rootlet-scars existing on the reverse side of the specimen. (Page 25.)

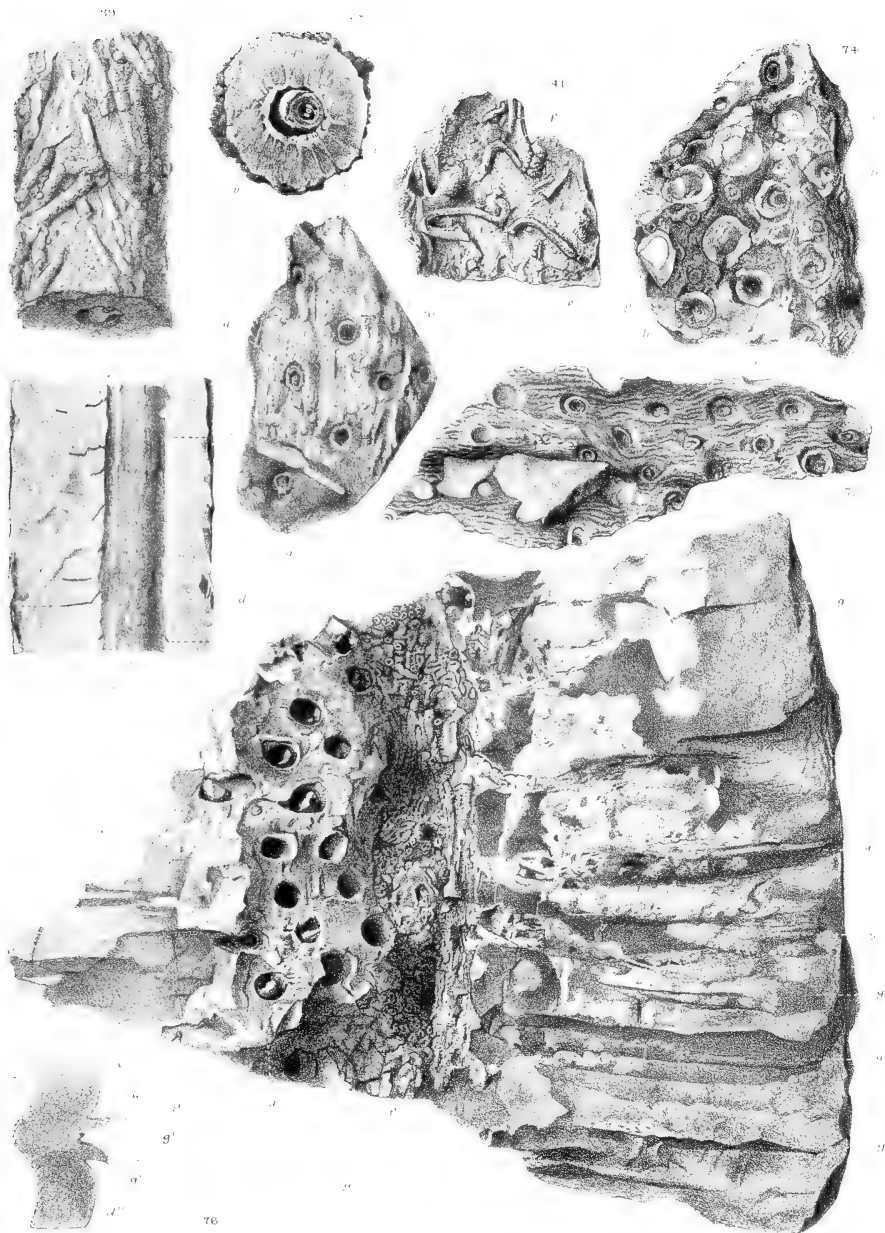
Fig. 70.—Fragment of the vascular cylinder of a Stigmaria, upon both surfaces of which the bases of rootlet-scars have been impressed on the disappearance of all the other cortical tissues. Nat. size. Author's Cabinet. (Page 37.)

Fig. 72.—Cast of the outer surface of a fragment of Stigmarian bark with undulating corrugations. Nat. size. Museum of the Owens College. (Page 38.)

Fig. 74.—Fragment of Stigmarian bark in which the bases of the rootlets are preserved as funnel-shaped depressions, within which the outer cortex of the rootlet forms a prominent ridge at *g*, and the conical apex of the rootlet cushion is seen at the bottom of the funnel, *h*. Nat. size. Author's Collection. (Pages 38, 40.)

Fig. 76.—Diagrammatic section of a Stigmarian rootlet attached to its bark, *d'*, *d''*, illustrating Figs. 74 and 75. Inner surface of the parenchymatous layer of the bark, *d'*. Outer surface of the same, *d''*. Small remnant of the outer cortex of the rootlet, *g''*, *g''*, being the point near which the rootlet, *g*, had been broken off from its basal end. Cylindrical interior of the base of the rootlet, *g'*, corresponding to the funnel-shaped depressions, *h*, of Fig. 74, and to the central prominences of Fig. 75. Apex of the cone of the rootlet cushion, *h*, forming the apical depression of each central prominence of Fig. 75. (Page 39.)









### PLATE XIII.

Fig. 27.—A dichotomous rootlet of *Stigmaria*. (Pages 32, 33.)

Fig. 64.—A natural cast of the medullary cavity of a Stigmarian root, the superficial longitudinal ridges of which represent the prolongations of the medulla into the inner extremities of the primary medullary rays. Nat. size. Hutton Collection. Newcastle Museum. (Page 35.)

Fig. 65.—Natural cast of half of the exterior of the vascular cylinder, *b*, of the same specimen as Fig. 64, showing the peripheral terminations of the primary medullary rays; mineral matter replacing the entire bark, *d*. Hutton Collection. (Page 36.)

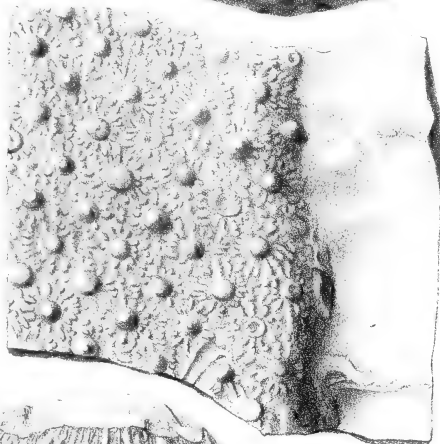
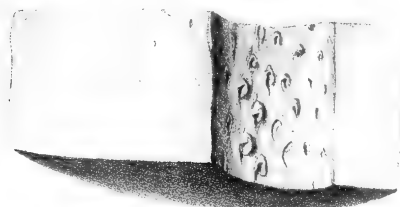
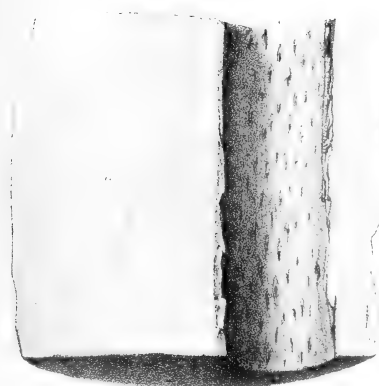
Fig. 66.—A second natural cast, like Fig. 65, showing much more strikingly the peripheral termination of the primary medullary rays. Nat. size. Hutton Collection. (Page 36.)

Fig. 67.—Transverse section of a Stigmarian root, nat. size, from which all organic elements have been removed. The inorganic matrix occupies the medullary cavity, *a*, the primary medullary rays, *b'*, and replaces the entire bark, *d*. Medullary rays, *b'*. Areas left vacant by the disappearance of the vascular wedges of the vascular cylinder, *b*. Hutton Collection. (Page 36.)

Fig. 71.—Cast or impression of the surface of part of a dichotomising Stigmarian root, exhibiting the casts of what were longitudinal fissures in the exterior of the bark, along with more minute undulating ridges and furrows. Half nat. size. Hutton Collection. (Page 37.)

Fig. 78.—A specimen from the Newcastle Museum of the *Stigmaria stellata* of Goepfert. (Page 40.)

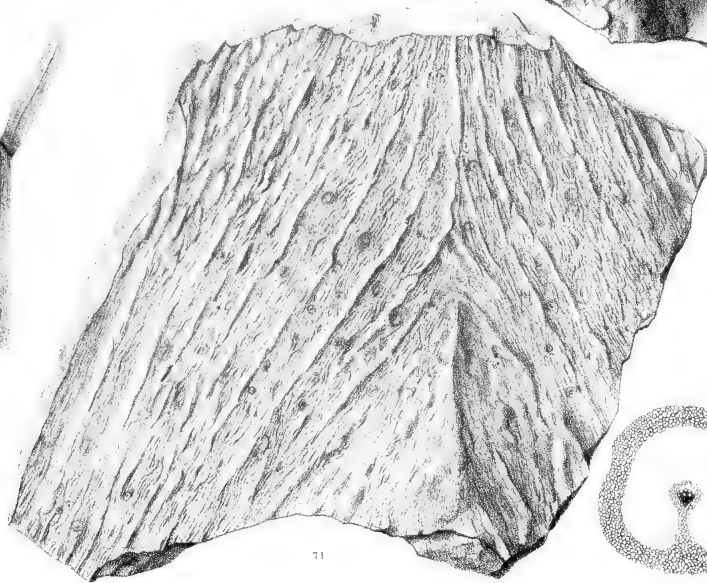
Fig. 79.—Transverse section of a Stigmarian rootlet in which the rootlet bundle and its rootlet cylinder, *f*, is united to the inner side of the rootlet-cortex, *g*, by a cellular lamina, *f''*, running longitudinally through the rootlet. (Page 32.)



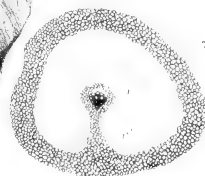
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#### PLATE XIV.

Fig. 68.—Fragment of a Stigmarian root split longitudinally. Exterior of medulla, *a*. Long section of the vascular cylinder, *b, b*. Primary medullary rays passing horizontally through the vascular cylinder, *b'*. Cortex replaced by inorganic matrix, *d, d*. Author's Cabinet. (Page 37.)

Fig. 69.—Exterior of the vascular cylinder of a Stigmaria, from Burntisland. Nat. size. Showing the large peripheral orifices of the primary medullary rays, *b, b*, intermingled with a few rootlet-scars. Author's Cabinet. (Page 37.)

Fig. 73.—A normal portion of a Stigmarian root deprived of its rootlets. Cavity left by the disappearance of the vascular cylinder, *b*, Nat. size. Author's Collection. (Page 38.)

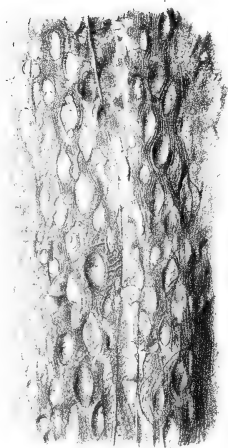
Fig. 75.—Cast of the outer surface of a Stigmarian bark which has been in the condition of the specimen, Fig. 74, and is illustrated by the diagram, fig. 76, Plate XII. Nat. size. Author's Collection. (Page 38.)

Fig. 77.—External surface of a Stigmarian bark, like Fig. 74, modified by shrinkage or compression. Nat. size. Author's Collection. (Page 40.)

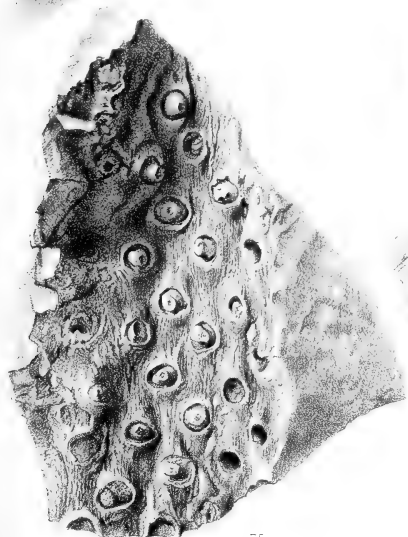
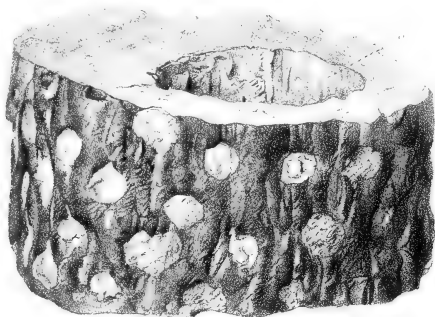




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PLATE XV.

Fig. 80.—View, taken obliquely from above, of a magnificent *Stigmaria ficoides*, recently discovered at Clayton, near Bradford, and now in the museum of the Owens College, Manchester. (Page 45.)











THE  
PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

VOLUME FOR 1886.

L O N D O N :

MDCCCLXXXVII.



A MONOGRAPH  
OF THE  
BRITISH  
FOSSIL SPONGES.

BY  
GEORGE JENNINGS HINDE, PH.D., F.G.S.

PART I.  
(PAGES 1—92. PLATES I—VIII.)

LONDON :  
PRINTED FOR THE PALEONTOGRAPHICAL SOCIETY.  
1887.

PRINTED BY  
ADLARD AND SON, BARTHOLOMEW CLOSE.

# A MONOGRAPH

## ON THE

### BRITISH FOSSIL SPONGES.

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#### INTRODUCTION.

THOUGH Fossil Sponges are mentioned in some of the earliest works in which fossils are treated of, and descriptions of them appear in nearly all subsequent works on palæontology, their true characters, until a comparatively recent date, were completely misunderstood, and their history was a mass of hopeless confusion. In the absence of any clear ideas as to the real nature of these organisms, the most heterogeneous materials were relegated to the group, and indeed it might be said to have been the practice—not altogether obsolete even now—to regard as a Sponge any fossil whose structure was too obscure to be satisfactorily placed elsewhere. One of the principal reasons for the chaos which existed was the erroneous idea, enunciated more particularly by D'Orbigny and Fromentel, that fossil Sponges belonged to an entirely extinct group, of a different nature to those now living, and consequently that no clue could be obtained to their original structures by a comparison with those of living forms.

Acting on this mistaken idea, those who studied the fossil forms did not attempt to carry out a systematic investigation of their skeletal structures, like that which had been so successfully applied to existing Sponges, but they were content to limit their investigations to the external form and the superficial canal structures, features possessed in common by many Sponges whose skeletal characters are essentially diverse. The classification thus based, was for the most part valueless and misleading. Here and there observers were not wanting who noticed the importance of the skeletal structures of these fossils, and amongst these Étallon deserves special mention; but no thorough attempt was made to apply the principle of the character of the skeleton, as the basis of classification, until that successfully carried out by Professor Zittel in 1877-78. Since the publication of Zittel's

'Studien ueber fossile Spongien' this principle has been recognised and acted on, and the status of fossil Sponges is no longer one of reproach and contempt. The impetus thus given to the study of these fossils is well shown by the various works on them which have since appeared in different countries, in which they are classified according to the minute characters of the spicular components of their skeletons, and the descriptions in the present work will be primarily founded on these features.

As preliminary to the description of the British forms I have thought it desirable to give a list of the principal works and papers treating of fossil Sponges generally, and short notices of their contents, in order to show, in chronological order, the views held respecting them at different times; and, further, to render the subject more readily intelligible to those who have not made a special study of this group of organisms, I have entered in some detail into the characters of the group generally, referring more particularly to the skeletal structures and to their condition of preservation, this last being a subject of special importance in connection with fossil Sponges, since the changes they have undergone have, in very many instances, completely masked their original features, and given rise to much of the misconception respecting their true characters.

## BIBLIOGRAPHY.

1. 1699 LUDIUS [Lhwyd], E. *Lithophylacii Britannici Ichnographia*.

In this, one of the earliest works in which the fossil remains of this country are noticed, the Sponges are placed under the common term *Aleyonium*, and included in the second class of *Lapides corallini*. Most of the forms referred to and figured are Calcisponges from Faringdon in Berkshire. One of the commoner examples is stated to be mineral cartilage.

2. 1705 PLOT, R. *Natural History of Oxfordshire*.

It is doubtful whether the forms represented as *Fungites* or *Tuberoides* are in reality Sponges or merely nodular flints from the Chalk.

3. 1708 BAER, J. J. *Oryctographia Norica*.

The fossil Sponges are referred to *Aleyonia* or *Fungi*. In the Supplement, published in 1730, very good figures are given of several species of Jurassic Sponges, which are placed in the family of the *Fungitæ* as marine fungi or *Aleyonia*. In a second Supplement, brought out in 1757 by the son of the original author, fresh examples of Jurassic lithistid and hexactinellid Sponges are figured and referred to the same groups. They are believed to be, together with other fossils, the relics of a common deluge.

4. 1708 LANGIUS, C. N. *Historia lapidum figuratorum Helvetiæ, ejusque vicinæ*.

The Sponges figured and mentioned are from Jurassic strata, and they are regarded as either fossil plants or fruits. The former, styled fungi, are placed under four species, and one of the latter is named *Aleyonia tuberosa*.

5. 1740 SCHEUCHZER, J. J. *Sciagraphia lithologica curiosa*.

Fossil Sponges are named *Aleyonia* and described as marine fungi.

6. 1742 BOURGET, L., et CARTIER, P. *Traité des Pétrifications*.

The Sponges figured are mostly the commoner forms of lithistids and hexactinellids from the Jurassic strata of Switzerland. They are stated to be marine plants and named 'Champignons de mer,' or 'Fruits de coralloide.'

7. 1751 GUETTARD, J. E. *Mémoire sur quelques corps fossiles peu connus (Mém. de l'Académie Royale des Sciences)*.

Denies that the fig-shaped bodies (*Siphonia*), of which numerous specimens are figured, have any relation to figs or other fruits, but states that they are Sponges, differing in form only from ordinary ones. Vasisform and cup-shaped Sponges are regarded as possessing more affinity to Madrepores than to Sponges.

8. 1775 KNORR, G. W., et WALCH, J. E. M. Recueil de Monumens des Catastrophes que la Globe de la Terre a esseeuées, contenant des pétrifications dessinées, gravées et enluminées d'après les originaux.

Many fossil Sponges are figured; some, apparently calcisponges, are regarded as Alcyonia, and their vents or oscules are stated to be the habitations of polypes. Siliceous hexactinellid and lithistid Sponges, from the Jurassic strata of Randen in Switzerland, are partly termed Fungites, and placed in the same group with genuine Corals, and partly placed under Escharites and Reteporites.

9. 1783 GUETTARD, J. E. Sur plusieurs corps marins fossiles de la classe des Coraux (*Mém. de l'Acad. Roy. des Sciences*, vol. iv, Pls. 1—29.)

There are numerous figures of lithistid Sponges; some are styled Caricoïdes and others Carico-Madreporites and Fungoïdes.

10. 1774–84 SCHROETER, J. S. Vollständige Einleitung in d. Kenntniss u. Geschichte d. Steine u. Versteinerungen.

Mentions a lithistid Sponge under the name of *Alcyonium ficus*, and regards it and other Alcyonia as Corals.

11. 1808 PARKINSON, J. J. Organic Remains of a Former World.

In the second volume, the nature of fossil Sponges is discussed in detail, and the author records the results of a series of painstaking observations and experiments of grinding them down and treating the surfaces with acid. They are placed under Alcyonium or Spongia, and fully believed to have been produced by animals, though the author could form no idea of their nature. The author discovered cruciform spicules in the dermal layer of a hexactinellid Sponge, and noticed the quadrate arrangement of the mesh in the Jurassic genus *Pachyteichisma*. Reference is also made to the Ventriculites in flint. Very good figures are given of numerous species of Sponges from Jurassic, Greensand, and Chalk strata; the author, however, does not assign to them distinctive names, but places them all under the common term Alcyonites.

12. 1814 WEBSTER, T. On some new varieties of fossil Alcyonia (*Transact. Geol. Soc.*, 1 S., vol. ii, p. 377, Pls. 27—30).

Describes and figures the lithistid Sponge now known as *Jerea Websteri*, under the name of *Tulip alcyonium*. Some specimens are erroneously stated to possess stems four to five feet in length.

13. 1815 MANTELL, G. A. Description of a fossil Alcyonium from the Chalk Strata of Lewes (*Transact. Linn. Soc.*, vol. xi, p. 401, Pls. 27—30).

Examples of the Sponge, described later by the same author as *Ventriculites radiatus*, are referred to under the name of *Alcyonium choroides*. These forms



are believed to have had powers of contraction and expansion, and the radiating ridges of the under surface of the Sponge are stated to be fasciculi of muscular fibres.

14. 1816 SMITH, W. Strata identified by Organised Fossils.

Figures are given of species of *Ventriculites* and *Cephalites* from the Upper Chalk under the name of flint Alcyonites. Specimens of *Doryderma*, *Siphonia*, and *Tremacystia* from the Upper Greensand are similarly placed under *Alcyonites*. These fossils are not described.

15. 1820 KÖNIG, C. Icones fossilium sectiles.

Four species of hexactinellid Sponges from Jurassic strata are placed in the genus *Spongos*, as Polypi, ordo incertus. The author remarks that these and similar fossils are usually regarded as Alcyonia, but that true Alcyonia are unknown in the fossil condition.

16. 1820 SCHLOTHEIM, E. F. v. Die Petrefaktenkunde.

In this work fossil Sponges are not distinguished from Corals. Some are named Fungiten and others Alcyonites, whilst under the term Spongiten are included true Corals.

17. 1820 SCHWEIGGER, A. F. Handbuch d. Naturges. d. skeletlosen ungegliederten Thiere.

Recent Sponges are regarded as Corals without polyps, and are placed under three leading groups or genera, *Achilleum*, *Manon* or *Tragos*, and *Scyphia*. These generic terms were subsequently very generally adopted for fossil Sponges.

18. 1821 LAMOUROUX, J. Exposition méthodique des Genres de l'ordre des Polypiers.

The fossil Sponges described and figured are classified in a peculiar manner. The genus *Eudea*, a calcisponge, is placed in the order Millepora; *Hallirhoa*, a lithistid, in the order Alcyonia, whilst the nearly allied genus *Jerea* is placed in the order Actinaires, together with *Chenendopora*, *Hippalinus*, and *Lymnoea*. These bodies are stated to have been soft in their living condition, and capable of expansion and contraction.

19. 1822 PARKINSON, J. An Introduction to the Study of Fossil Organic Remains.

Fossil Sponges are definitely recognised as of the same nature as recent forms, and their occurrence is noted in the Lower Greensand of Faringdon, the Upper Greensand of Wiltshire, and in the flints of the Upper Chalk. They are placed in the tribe Zoophytes. The genus *Siphonia* is defined, and its principal character is stated to be "a spongy substance, pierced by a bundle

of tubes." Many different forms of Sponges are included in the genus, but the specimen first referred to it, and therefore the type of the genus, is now known as *Siphonia Kænigi*, Mant. Another genus, *Mantellia*, is proposed to include *Alcyonium chonoides*, Mant., but the characters given are very indefinite, and the specimen figured as an example does not belong to the same genus as Mantell's species.

20. 1822 MANTELL, G. A. The Fossils of the South Downs, &c.

Many of the commoner fossil Sponges from the Upper Chalk are described and figured. Some are referred to *Alcyonites*, others to *Spongos* and *Spongia*. The genus *Ventriculites* is constituted; the forms are believed to have been originally of a spongy or gelatinous substance, possessing contractile properties. The genus *Choanites* is proposed, but the characters given are too indefinite to be of any value, and the three species placed under it belong to as many different genera.

21. 1829 ROSE, C. B. On the Anatomy of the *Ventriculites* of Mantell (*Mag. Nat. Hist.*, vol. 2, p. 332).

The author agrees with Mantell that they are retractile, and they are stated to consist of an inner coat, with the openings of transverse tubes, a reticulated parenchyma, and an external coat, partly of a coriaceous and elastic integument. Each *Ventriculite* is regarded as a single gelatinous polype.

22. 1816-30 Dictionnaire des Sciences Naturelles.

The classification of Lamouroux is adopted generally for fossil Sponges. The genus *Receptaculites* is described as probably belonging to the Polypiers, and the doubtful genus *Verticillites* is also placed in the same group.

23. 1831 BENETT, E. A Catalogue of the Organic Remains of the County of Wilts; Pls. 1—15.

Excellent figures are given of numerous forms of lithistid Sponges from the Upper Greensand and the Upper Chalk. The Sponges are not described, but they are included in the common term *Polypothecia*. Specimens of *Camerospongia* are placed under *Choanites*, Mant.

24. 1826-33 GOLDFUSS, A. Petrefacta Germaniæ, vol. i.

Fossil Sponges are regarded as the remains of Zoophytes, the plant-animals of the past. Numerous new species are described, and they are, for the most part, placed under the indefinite generic terms proposed by Schweigger for living keratose Sponges. The genus *Siphonia*, Park., is more strictly defined, and the new genera *Cnemidium*, *Myrmecium*, *Coscinopora*, and *Cœloptychium* are instituted, principally on their external characters. The spicular structure is only referred to as reticulate or lattice-shaped fibres or threads, which

are supposed to have been soft and gelatinous in the living condition. Most of the Sponges are from the Jurassic and Cretaceous strata. The figures are very faithful; in some instances the spicular structure has been represented, as well as the Sponge itself.

25. 1833 WOODWARD, S. An Outline of the Geology of Norfolk.

Under the heading of Polypi a list of seven species of Sponges is given, in which *Cæloptychium agaricoides*, Goldf., and *Ventriculites infundibuliformis*, n. sp., are included. These are figured but not described.

26. 1834 BLAINVILLE, H. M. DE. Manuel d'Actinologie.

Sponges are placed in the group Amorphozoaires; fossil Sponges are regarded as of the same nature as living ones, and, in some cases, both fossil and existing species are placed (though incorrectly) in the same genus. The author accepts Goldfuss's theory respecting the character of their fibres. For Sponges with skeletal spicules of carbonate of lime, the term Calcispongia is proposed. The figures given are mostly reproductions from the works of Lamouroux and Goldfuss.

27. 1835 PHILLIPS, JOHN. The Geology of Yorkshire, vol. i.

Names are given to fifteen of the commoner species of Sponges from the Upper Chalk of Flamborough, Yorkshire. They are included under the generic term *Spongia*; there are no descriptions, and the figures are of so rude a character that there is great difficulty in recognising the forms supposed to be represented.

28. 1836 SOWERBY, J. DE C. Descriptive Notes, &c. (*Trans. Geol. Soc.*, ser. 2, vol. iv).

A description is given of *Siphonia pyriformis* (now *S. tulipa*, Zitt.) from the Upper Greensand, Blackdown, and on Pl. XV A, excellent illustrations are furnished of various examples showing the canal-structures.

29. 1837 HISINGER, W. Lethæa suecica.

Two species of *Siphonia* (now *Astylospongia*) are mentioned, *S. præmorsa* and *S. stipitata*.

30. 1839 ROEMER, F. A. Die Versteinerungen des norddeutschen Oolithen-Gebirges. Nachtrag.

The fossil Sponges are mostly calcisponges; they are placed under *Tragos* and *Scyphia*.

31. 1839 LEE, J. E. Undescribed Zoophytes from the Yorkshire Chalk (*Mag. Nat. Hist.*, vol. iii, pp. 10—17, figs. 1—15).

The forms are lithistid Sponges, which are placed in the genera *Siphonia* and *Spongia*; only their superficial characters are referred to.

32. 1839 BRONN, H. G. *Lethæa geognostica*.

In this work the following genera of fossil Sponges from Oolitic and Cretaceous strata are stated to possess an internal fibrous reticulated structure, *Scyphia*, *Tragos*, *Mammillopora*, *Cnemidium*, *Myrmecium*, and *Hippalimus*. Some of these genera are supposed to include horny Sponges, both recent and fossil.

33. 1839 HAGENOW, F. v. *Monographie der rügenschens Kreideversteinerungen* (*Neues Jahrb.*, p. 260).

The Sponges are placed with Corals and Polyzoa as Polyparien. Species of *Achilleum*, *Manon*, *Scyphia*, and *Siphonia* are named, and references given.

34. 1839 MURCHISON, R. I. *Silurian System*.

Names and gives a figure of *Ischadites Kœnigii* (p. 697, Pl. xxvi, fig. 11). Its affinities are considered very doubtful.

35. 1840 ROEMER, F. A. *Die Versteinerungen des norddeutschen Kreidegebirges*.

Numerous species of Sponges, many of them new, are described. They are for the most part placed in the meaningless genera, *Spongia*, *Achilleum*, *Manon*, *Tragos*, *Cnemidium*, and *Scyphia*. The new genus *Pleurostoma* is constituted. The descriptions are very brief and indefinite, and regard chiefly external characters. The minute spicular structure of many hexactinellid Sponges is described as lattice-shaped fibre and distinctly figured, but these Sponges are included in the same genus with lithistid and calcisponges.

36. 1841 MÜNSTER, GRAF ZU. *Beiträge zur Petrefacten-Kunde*.

Numerous species of Calcisponges from the St.-Cassian beds are described and figured. They are regarded as polyps and placed in the genera *Achilleum*, *Scyphia*, &c.

37. 1842-44 KONINCK, L. DE. *Description des Animaux fossiles dans le terrain carbonifère de Belgique*.

Describes as a new genus of Corals, *Mortiera*; a biconcave siliceous fossil, composed of thin lamellæ. It is now regarded as a Sponge (P. 12, Pl. B, fig. 3).

38. 1842 BOWERBANK, J. S. *On the Spongy Origin of Moss-agates and other Siliceous Bodies* (*Ann. and Mag. Nat. H.*, vol. x, pp. 9, 84, Pls. i—iii).

The fibrous appearances in sections of moss-agates are stated to be due to the presence of keratose Sponges, and the chert of the Greensand strata and the flints from the Chalk are believed to have been produced by the continued attraction and solidification by keratose Sponges of the silex in solution in the ocean.

39. 1842 BOWERBANK, J. S. On the Siliceous Bodies of the Chalk, Greensands, and Oolites (*Trans. Geol. Soc., Lond.*, 2 S., vol. vi, pp. 181—194).

Regards the flints of the Chalk and the chert in the Greensand and Oolites as Sponges which have been filled in with silica, attracted by the animal matter of the Sponge, and not by the presence of the spicules.

40. 1843 KLIPSTEIN, E. Beiträge zur geologischen Kenntniss der oestlichen Alpen.

The Sponges are mostly calcisponges from the St. Cassian beds, which are placed in the same genera as those previously described by Count Münster. They are regarded as coral-polyps with a structure of reticulate fibres.

41. 1843 GEINITZ, H. B. Die Versteinerungen von Kieslingswalda.

New species of hexactinellids, lithistids, and probably of calcisponges from the lower Pläner of Plauen are placed under *Cnemidium*, *Tragos*, and *Manon*.

42. 1843 QUENSTEDT, F. A. Das Floetzgebirge Württembergs.

The Sponges from the limestone strata of the Middle White Jura, which, for the most part, had been already figured by Goldfuss, are here described in greater detail. The lattice-like, "gitterformig," structure of many hexactinellids is recognised, but such forms are nevertheless included with lithistids and calcisponges in the undefined genus *Spongites*. Other lithistids are placed under *Cnemidium* and *Tragos*.

43. 1843 PORTLOCK, J. E. Report on the Geology of Londonderry.

Various species of Cretaceous hexactinellid and lithistid Sponges are placed in the genera *Achilleum*, *Ventriculites*, *Scyphia*, *Coscinopora*, and *Siphonia*. A bundle of spicular rods forming the anchoring rope of a hexactinellid Sponge is described as a species of *Serpula*.

44. 1845 REUSS, A. E. Die Versteinerungen der böhmischen Kreideformation.

The Sponges are placed under Amorphozoa. The author states that the genera recognised by Goldfuss are without practical value, and yet he does not discard them. Good detailed descriptions and figures are given of the various species so far as their form and canal-structures are concerned, but no special importance is given to their spicular structures, which are described as a meshwork of reticulate fibres. The species are nearly entirely of lithistid and hexactinellid Sponges. The genus *Plocoscyphia* is defined.

45. 1846 D'ARCHIAC. Description des Fossiles des environs de Bayonne (*Mém. de la Soc. Géol. de France*, S. 2, T. 2, p. 197, Pl. V, fig. 15 a; Pl. VIII, figs. 5—7).

Describes as a new species, *Guetardia Thiolati*, stated to be derived from Tertiary strata at Biarritz.

46. 1846 PICTET, F. E. *Traité élémentaire de Paléontologie*, Tome iv.

Fossil Sponges are placed in the group of Amorphozoaires of Blainville, but it is considered doubtful whether they possessed true polyps, like Alcyonia, or were without them. They are for the most part regarded as true horny Sponges, but it is supposed that some genera, such as *Siphonia*, *Jerea*, *Myrmecium*, and others, may have been provided with true polyps, and therefore belonged to Corals.

47. 1840-47. MICHELIN, H. *Iconographie Zoophytologique*.

Numerous species of Sponges from the Cretaceous and Jurassic strata of France are described and figured. The descriptions are very brief and refer merely to the superficial characters. Nothing definite is stated respecting the nature of fossil Sponges, but they are apparently regarded as of the same character as recent horny Sponges, which have become siliceous or calcareous by fossilisation. They are mostly placed under the genera *Spongia*, *Jerea*, *Siphonia*, &c., of previous authors. Two new genera, *Guettardia* and *Turonia*, are proposed.

48. 1847 OSWALD, F. Ueber die Petrefacten von Sadewitz (*Uebersicht Arbeit. und Verand. Schles. Gesell.*, p. 56).

Defines the Silurian genus *Aulocopium*, and places under it fourteen species, the names only of which are given. Species of *Scyphia* and *Tragos* are similarly named, but not described.

49. 1847-48 SMITH, J. TOULMIN. The Ventriculidæ of the Chalk (*Ann. and Mag. Nat. Hist.*, vol. xx, pp. 73, 176, Pls. VII, VIII, and 2nd ser., vol. i, pp. 36, 203, 279, 352, Pls. XIII-XVI).

The minute structure, though not the true nature of fossil hexactinellid Sponges, is for the first time fully described. They are shown to consist of thin, variously folded membranes, formed of a rectangular tissue of anastomosing fibres, which at the points of intersection possessed hollow or octahedral nodes. Several different kinds of tissue, that of the substance of the body, a finer subdermal membrane, an exterior membrane, and that of the root-fibres are described, the nodes of this latter not being hollow. The membranes are not believed to have been originally of a mineral nature, but are regarded as replacements by silica, iron, or lime of the original animal structures. The fossils are regarded by the author not as Sponges, but as the skeletons of polyzoa or ascidian polypes, in opposition to the opinion of Prof. John Morris that they were Amorphozoa or Sponges. They are placed in the genera *Ventriculites*, *Cephalites*, and *Brachiospongia*. This last is obsolete, as it is only a synonym of the previously constituted *Plocoscyphia*, Reuss, and *Guettardia*, Mich.

50. 1848 ROEMER, FERD. Ueber eine neue Art der Gattung *Blumenbachium*, Koenig, und mehre unzweifelhafte Spongien in Obersilurischen Kalkschichten der Grafschaft Decatur im Staate Illinois in Nord America (*Leonhard u. Bronn's Neues Jahrbuch*, pp. 680—686, Pl. IX).

Recognises the similarity in the nature of the spicules of *Blumenbachium meniscus* (now *Astræospongia*) to that of living siliceous Sponges. Undoubted Sponges from the Silurian strata (Niagara group) of North America are compared with Cretaceous Sponges and placed in the genus *Siphonia*. Subsequently the author placed these forms in a distinct genus, *Astylospongia*.

51. 1848 M'Coy, F. On some new Mesozoic Radiata (*Ann. and Mag. Nat. Hist.* 2nd ser., vol. ii, p. 397).

Describes the superficial characters of four species of Cretaceous and Oolitic Sponges. No figures are given.

52. 1848 MANTELL, G. A. Wonders of Geology, 6th edition.

In this edition various species of Sponges from the Chalk and Greensand are figured, and referred to in general terms as Sponges and Zoophytes. *Ventriculites* is still stated to have been contractile.

53. 1848 CHARLESWORTH, E. On the Mineral Condition and General Affinities of the Zoophytes of the Chalk at Flamborough and Bridlington (*Proc. Yorks. Phil. Soc.*, vol. i, p. 73).

These Sponges are apparently regarded as having been originally of a horny character, and attention is called to the fact that their tissues are now silicified. The different species named by Phillips are believed to be merely modifications of a single form, for which the author proposes the name *Rhizospongia polymorpha*.

54. 1849–52 D'ORBIGNY, A. Prodrôme de Paléontologie.

The Sponges are placed under Amorphozoa, numerous genera and species are introduced, but the characters given are so brief and indefinite that, in the absence of figures, it is impracticable to recognise them satisfactorily.

55. 1850 KING, W. Monograph of the Permian Fossils (*Pal. Soc.*, pp. 11—14, Pl. 2).

Refers some doubtful organisms to the genera *Scyphia*, *Mammillopora*, *Tragos*, and *Bothroconis*, n. g. Only their external characters are described.

56. 1850 DIXON, F. Geology and Fossils of Sussex.

Some specimens and polished surfaces of *Siphonia* in flint are figured, but nothing is stated of them beyond the fact that they are Sponges.

57. 1851 MORRIS, J. Palæontological Notes (*Ann. and Mag. Nat. Hist.*, 2nd ser., vol. 8, p. 88).

Refers to the cavities, now infilled with silica, in Cretaceous *Inocerami* and *Belemnitella*, and regards them as produced by the borings of Sponges, like *Cliona*.

58. 1852 WETHERELL, N. T. Note on a New Species of *Clionites* (*Ann. and Mag. Nat. Hist.*, 2nd ser., vol. x, p. 354, Pl. 5, figs. 1, 2).

Describes small oval infillings in the shell of *Inoceramus*, which, however, do not appear to have any relation to boring Sponges.

59. 1852 GIEBEL, E. G. Deutschlands Petrefacten.

The Sponges are placed under Amorphozoa. References are given to the description, geological position, and place of occurrence of 148 species from the strata of Germany.

60. 1852 QUENSTEDT, F. A. Handbuch der Petrefaktenkunde.

References are made to most of the Jurassic species of Sponges described by Goldfuss, as well as to *Ventriculites* and *Siphonia*. The external characters and canal structures are described in detail. The similarity of the skeleton of some of the Jurassic Sponges to that of *Ventriculites* is recognised, as well as the resemblance of detached fossil Sponge spicules to those of existing Sponges. Fossil Sponges generally are stated to consist of interwoven fibres, between which calcareous or siliceous spicules occur, but the spicular nature of the fibre itself is not noticed.

61. 1852 D'ORBIGNY, A. Cours élémentaire de Paléontologie.

Sponges are placed in the group Amorphozoaires of Blainville, their skeletons are stated to be either "corné" or "testacé," fibreux "or" "poreux." The author denies that fossil Sponges ever possessed a horny skeleton, like many living forms, but states that they were always calcareous and stony. Sponges generally are placed in two groups; those with horny skeletons, of which the only fossil representatives are species of *Cliona*, and those with stony (testacé) skeletons, which are exclusively fossil, and no longer exist. For these latter the following families are proposed:—(1) *Ocellaridæ*; (2) *Siphonidæ*; (3) *Lyxnoreidæ*; (4) *Sparsispongidæ*, and (5) *Amorphospongidæ*. The skeletal characters are referred to in a general manner as filamentous tissues, and no distinction is made between siliceous sponges and calcisponges. Numerous new genera are introduced, but their characters are too indefinite to possess any value.



62. 1854 EHRENBURG, C. G. Mikrogeologie.

Numerous detached Sponge spicules from fossil and sub-fossil deposits are figured, but no reference to their characters is given; the general term *Spongolithis* is applied to them all, and a distinctive name is given to every variety of form, though evidently many of these belong to the same species.

63. 1854 SHARPE, D. On the Age of the Fossiliferous Sands and Gravels of Faringdon (*Quart. Journ. Geol. Soc.*, vol. x, p. 176, Pl. V).

Sixteen species of fossil Sponges are enumerated; some new forms are placed in the genus *Manon*, and others are erroneously referred to species described by Lamouroux and Goldfuss from the Upper Greensand. No reference is made to the fact that the Faringdon examples are exclusively calcisponges.

64. 1854 MANTELL, G. A. Medals of Creation, 2nd edition.

It is stated, in opposition to D'Orbigny, that keratose Sponges are abundant as fossils. Most of the Sponges from the Chalk and Greensand are apparently referred to this group, and included under *Spongites*. *Siphonia* and *Choanites* are regarded as distinct genera; the latter is supposed to have been originally of a soft gelatinous substance strengthened by spicula, but the spicula figured do not belong to this genus.

65. 1854 MORRIS, J. A Catalogue of British Fossils, 2nd edition.

Under the heading *Amorphozoa*, 148 species of Sponges are enumerated, which are placed in thirty-one genera. About nineteen of these genera are now regarded as obsolete.

66. 1855 M'Coy, F. Systematic Description of the British Palæozoic Fossils in the Geological Museum of the University of Cambridge.

In a footnote it is stated that no *Amorphozoa* are described in the work, but two species of *Steganodictyum* (now known to be the shields of fishes) are figured as Sponges. *Pyritonema fasciculus*, the root-appendage of a hexactinellid Sponge, is compared with *Hyalonema*, then regarded as a Zoophyte; and *Tetragonis Danbyi* (now *Dictyophyton*) is placed in the order Cystidea.

67. 1858 ELEY, H. Geology in the Garden, or the Fossils in the Flint Pebbles.

Describes and figures various forms of detached monactinellid, tetractinellid and hexactinellid spicules from the interior of flints, and concludes that Sponges were most prevalent in the Chalk Seas (pp. 177—184, Pl. I).

68. 1858 QUENSTEDT, F. A. Der Jura.

Specific descriptions, limited, however, to superficial characters, are given of most of the Jurassic Sponges, and the previous classification of the author is followed.

69. 1859 FROMENTEL, E. DE. Introduction à l'Étude des Éponges Fossiles (*Mém. de la Soc. Linnéenne de Norm.*, T. xi, pp. 1—50, Pls. I—IV).

The group of Sponges is placed under two main divisions, that of Spongiaires or living Sponges, with a skeleton of spicules, or of spicules and horny fibres; and that of Spongitaires or fossil Sponges, in which the skeleton consists of a stony meshwork, which may or may not include spicules. The classification proposed is based mainly on the nature of the canal-system, and an altogether subordinate value is placed on the characters of the skeleton. Fossil Sponges are divided into the following suborders, *Spongitaria tubulosa*, *S. osculata*, and *S. porosa*. The classification is not a natural one since it includes various forms of siliceous sponges and calcisponges in the same family.

70. 1859 THURMANN, J., et ETALLON, A. Lethæa Bruntrutana, ou Études Paléontologiques et Stratigraphiques sur le Jura Bernois, et en particulier les environs de Porrentruy (*Nouv. Mém. de la Soc. helvétique des Sciences natur.*).

Numerous species of Sponges, for the most part calcisponges apparently, are described, but only their superficial characters are referred to.

71. 1860 FROMENTEL, E. DE. Catalogue raisonné des Spongitaires de l'Étage Néocomien (*Bullet. de la Soc. des Sciences de l'Yonne*, 4<sup>e</sup> Série, pp. 1—19, Pls. I—IV).

Three new genera and several new species are introduced; the same classification is adopted as in the author's 'Introduction,' and it is stated to be based on positive and natural characters.

72. 1860 ETALLON, A. Sur la Classification des Spongiaires du Haut Jura et leur distribution dans les Étages (*Actes de la Société Jurassienne d'Emulation pendant 1858*, pp. 129—160, Pl. I).

Describes very clearly the true character of the skeleton of hexactinellid Sponges as consisting of spicules amalgamated at their points so as to form a regular cubic network. These Sponges are placed in the family of the Dictyonocœlides. In the family of the Petrospongides the skeleton is supposed to be without spicules, and this family apparently includes calcisponges. A third family is named Clonides. Lithistid Sponges are not particularly noticed, and they are not comprised in the definition of the proposed groups. The author was one of the first to recognise the value of the skeletal structures of fossil Sponges as a basis of classification.

73. 1860 CAPELLINI und PAGENSTECHER. Mikroskopische Untersuchungen über den innern Bau einiger fossilen Schwämme (*Zeitsch. f. wiss. Zoologie*, Bd. x, p. 364, Pl. xxx).

The spicular structure of several species of hexactinellid Sponges from the

Jurassic strata of St. Claude is described and the presence of canals in the axes of the spicules is noted, and their resemblance to the *Ventriculites* of Toulmin Smith is pointed out. This siliceous skeleton is stated to correspond to the horny skeleton of living Sponges, and cannot be compared to the spicules of existing forms.

74. 1860 D'EICHWALD, E. *Lethæa Rossica*, vol. i, p. 325.

Describes species of *Scyphia*, *Siphonia*, *Thoosa*, and of several other genera, but judging from the characters and the figures it is very doubtful if any of the forms are genuine Sponges.

75. 1860 ROEMER, FERD. *Die Silurische Fauna des westlichen Tennessee*.

Describes in greater detail than hitherto various species of *Astylospongia*, also proposes the genus *Palæomanon* for cup-shaped Sponges with the same spicular structure as *Astylospongia*. *Astræospongia* is regarded as a Calci-sponge.

76. 1861 OWEN, R. *Palæontology*, pp. 5—8.

Sponges are placed under the class Amorphozoa and brief reference is made to their distribution in British strata. Calcareous Sponges are stated to abound in the Oolitic and Cretaceous strata, attaining their maximum development in the Chalk. No reference is made to the structure of *Ventriculites* or of *Guetbardia*. *Siphonia* and the allied genera, grouped together as Petrospongiadæ, are stated to possess a stony reticulated frame without spicules and to have passed away with the Secondary epoch.

77. 1861 GEINITZ, H. B. *Die animalischen Ueberreste der Dyas*, pp. 123, 124, Pl. XX.

Refers to two species of *Spongia* some fossils of doubtful character, and copies the descriptions given by King of the reputed Sponges from the English Permian.

78. 1861 COUETILLER, A. *Éponges fossiles des Sables du Terrain Crétacé supérieur des environs de Saumur* (*Ann. de la Soc. Linn. de Maine-et-Loire*, 4<sup>e</sup> vol., pp. 1—26, Pls. I—XL).

Numerous species are described and referred to various genera. Only their superficial characters are noticed, and the species have thus little, if any, value.

79. 1861 ROEMER, FERD. *Die fossile Fauna der silurischen Diluvial-Geschiebe von Sadewitz*.

Several new species of *Astylospongia* are described; the spicular structure of the genus is stated to consist of very regular six-rayed, star-shaped bodies, so united together that the rays of one star are intimately united with those

of the proximately adjoining stars. The genus *Aulocopium*, Oswald, is further defined, and several new species included therein; its intimate structure is stated to be a fibrous tissue. A fresh species of *Astræospongia* is also described.

80. 1861 SALTER, J. W. Mem. Geol. Surv. of Great Britain; 32, Scotland, p. 135, Pl. II, figs. 3, 3 a.

Describes and figures *Amphispongia oblonga* from the Silurian of the Pentland Hills, as a calcisponge allied to *Grantia*.

81. 1861 LORIOU, P. DE. Description des animaux invertébrés contenus dans l'étage Néocomien moyen du Mont Salève.

Numerous species of Sponges are described and figured, only their external characters are referred to, and the classification of Fromentel is adopted. The forms are evidently calcisponges for the most part, with one or two species of hexactinellids.

82. 1862<sup>1</sup> GRIFFITH and M'Coy. A Synopsis of the Silurian Fossils of Ireland.

A single Sponge is described under the name of *Acanthospongia Siluriensis*. The spicules are stated to be of the shape of the letter X, and to possess six rays. No figure is given.

83. 1863 HALL, J. Observations upon the genera *Uphantænia* and *Dictyophyton* (*Sixteenth Annual Report of the New York State Museum of Natural History*, p. 84, Pls. iii—v, v a).

These fossils, now regarded as Sponges, are described as Algæ of a peculiar form and mode of growth. Numerous species are figured and referred to.

84. 1863 HALL, J. Note on the Occurrence of *Astylospongia* in the Lower Helderberg Rocks (*Sixteenth Annual Report of the New York State Cabinet*, p. 69).

A globose body is described under the name of *Astylospongia inornata*, but there is no account of its internal structure, and it is probably wrongly referred to this genus.

85. 1864 ROEMER, F. A. Die Spongitarien des norddeutschen Kreidegebirges (*Palæontographica*, Bd. xiii, pp. 1—63, Pls. I—XIX).

In this important work the artificial systems of classification of D'Orbigny and Fromentel are adopted, with the result of uniting into the same group Sponges whose structures are very distinct. The tissue of fossil Sponges is regarded as either lattice-like or vermiculate. The former is stated to consist of very thin, smooth, siliceous rods, which grow together so as to make a lattice-like web, with octahedral nodes. The vermiculate fibres may be either siliceous or calcareous; in the former case the structure resembles the lattice-

<sup>1</sup> The date on the title-page of this book is 1846, but it was not published and sold until 1862.

like tissue, and it is likewise composed of spicules. Thus, whilst hexactinellid Sponges are, for the most part, by themselves, lithistid and calcisponges are united into one group. Numerous species are described and figured, but the characters given are very brief and inadequate for satisfactory recognition.

86. 1864 SALTER, J. W. On some new Fossils from the Lingula Flags of Wales (*Quart. Jour. Geol. Soc.*, vol. xx, p. 238, Pl. XIII).

Describes, as a new genus and species, *Protospongia fenestrata*, from Menevian strata. It is stated to possess a reticulate skeleton of large cruciform spicula.

87. 1864 FROMENTEL, E. DE. Polypiers Coralliens des Environs de Gray (*Mém. de la Soc. Linn. de Norm.*, vol. xiii).

Various species of calcisponges are figured on Pl. xv.

88. 1865 BILLINGS, E. Palæozoic Fossils, vol. i (*Geological Survey of Canada*).

An elaborate description is given of the characters of the genus *Receptaculites*, which is regarded as probably a Sponge. The spicules are compared with the birotulate forms in the gemmules of the freshwater *Spongilla*. *Archæocyathus*, *Calathium*, and *Eospongia* are also described provisionally as Sponges.

89. 1865 DE FERRY. Note sur les Crustacés et les Spongitaires de la base de l'étage Bathonien des environs de Macon (*Bull. de la Soc. Linn. de Normandie* (Caen), vol. ix, pp. 365—375).

Silicified bodies of irregular form are referred to the genera *Siphonocælia* and *Discælia*. Their affinities appear to be very doubtful.

90. 1865 LAUBE, G. C. Die Fauna der Schichten von St. Cassian (*Denkschrift d. k. Akad. d. Wiss. Wien*, Bd. 24).

Numerous species of calcisponges are described, but no information is given respecting their skeletal structures.

91. 1865 TATE, R. On the Correlation of the Cretaceous Formations of the North-East of Ireland (*Quart. Journ. Geol. Soc.*, vol. xxi, p. 43, Pl. V).

Two new genera of hexactinellid Sponges are proposed, *Etheridgia* and *Cæloscyphia*; and two species of *Cæloptychium* are regarded as new forms.

92. 1866 MACKIE, S. J. An Illustrated Catalogue of British Fossil Sponges, Part II, pp. 1—32, Pls. I—IV.

Only the second part of this extraordinary work appeared. It consists of numerous extracts from the writings of Mantell, Toulmin Smith, and other authors on fossil Sponges, mingled with desultory remarks of the author himself. None of the figures on the four plates appears to be original.

93. 1866 SUESS, E. On the existence of *Hyalonema* in a Fossil State (*Ann. and Mag. Nat. Hist.*, 3 S., vol. 18, p. 404).

States that the *Serpula parallela* of the Yorkshire Mountain-Limestone is a true glass-rope, and that it should be named *Hyalonema parallellum*.

94. 1867 MARSH, O. C. Notice of a New Genus of Fossil Sponges from the Lower Silurian (*Amer. Journ. Sci.*, S. 2, vol. 44, p. 88).

Describes the genus *Brachiospongia*, but its minute structure is not stated.

95. 1867 REUSS, A. E. Die Bryozoen, Anthozoen, und Spongarien des Braunen Jura von Balin bei Krakau (*Denks. d. k. Akad. d. Wiss. Wien*, Bd. 27).

Five species, apparently all calcisponges, are recorded, two of them, *Jerea biceps* and *Siphonocælia gregaria* as new forms.

96. 1867 ROSEN, Baron von. Ueber die Natur der Stromatoporen, und über die Erhaltung der Hornfaser der Spongien im fossilen Zustande.

This work more particularly treats of forms of *Stromatopora*, which are regarded as fossilized horny Sponges. These bodies are compared with genuine hexactinellid and lithistid Sponges from the Chalk of Saratow, which are believed to have had originally skeletons of a horny nature. The silicified Sponges are stated to be produced by the change of horny fibre into silica.

97. 1868 FISCHER, M. P. Recherches sur les Éponges perforantes fossiles (*Nouv. Archiv. du Mus. d'Histoire Naturelle*, pp. 117—172, Pls. XXIV—XXX).

Sketches the history of these bodies, and describes and figures the known forms. States that *Entobia antiqua*, Portlock, is most probably a Bryozoan, and doubts that *Vioa prisca*, M'Coy, is due to a boring Sponge.

98. 1868 LORIOU, P. DE. Monographie des Couches de l'Étage Valangien des carrières d'Arzier (*Matériaux pour la paléontologie Suisse*, par Pictet).

The forms described, judging from the figures, are all calcisponges. Only their superficial characters are referred to, and they are ranged according to the classification of Fromentel.

99. 1868 KOSTYTSCHEF, A., und MARCGRAF, O. Ueber die Chemische Zusammensetzung der in dem Apatitsandstein der russischen Kreideformation vorkommenden versteinerten Schwämme (*Bull. de l'Acad. de St.-Petersb.*, vol. xiii, pp. 19, 20, 1869).

No reference is given to the kinds of Sponges which were analysed; the specimens consisted principally of phosphate of lime, of a similar composition to the fossilised wood and bones in the same deposit.

100. 1868 BIGSBY, J. J. *Thesaurus Siluricus*.

Under Amorphozoa a list of 119 species is given, but about 70 of these may be definitely excluded from Sponges, and many others are undetermined or doubtful forms.

101. 1868 LANKESTER, E. RAY. On the Discovery of the Remains of Cephalaspidian Fishes in Devonshire and Cornwall; and on the Identity of *Steganodictyum*, M'Coy, with Genera of those Fishes (*Quart. Journ. Geol. Soc.*, vol. 24, p. 546).

Records that Mr. Salter determined that M'Coy's supposed Sponges, placed under *Steganodictyum*, are actually the cephalic plates of Pteraspidian fishes. Confirms this determination, and places the *Steganodictyum cornubicum*, M'Coy, under *Scaphaspis*, and *S. Carteri*, M'Coy, as allied to *Cephalaspis*.

102. 1868 MEEK and WORTHEN. Palæontology of Illinois, vol. 3.

Species of *Receptaculites* and *Astræospongia* are described and figured.

103. 1869 TRAUTSCHOLD, H. Palæontologischer Nachtrag (*Bull. de la Soc. Imp. des Naturalistes de Moscou*, p. 230, Pl. i).

Describes under the name of *Siderospongia sirenis* a platter-shaped body whose surface is covered with star-like canals. The nature of the organism is very doubtful.

104. 1869 BOWERBANK, J. S. Monograph of the Siliceo-fibrous Sponges (*Proc. Zool. Soc.*).

Describes, amongst others, *Purisiphonia* as a new genus intermediate between *Dactylocalyx* and *Farrea* (p. 342). The only species, *P. Clarkei*, is probably from the Cretaceous strata of Queensland.

105. 1870 ROEMER, FERD. Geologie von Oberschlesien.

Numerous siliceous Sponges are referred to and figured; for the most part they belong to species already known.

106. 1870 PARFITT, E. Fossil Sponge Spicules in the Greensand of Haldon and Blackdown (*Transact. Devon. Assoc.*, vol. iv, pp. 138—144, 1 Pl.).

Detached spicules, resulting from the disintegration of tetractinellid and lithistid Sponges, are described and figured, and they are compared with the spicules of existing Sponges.

107. 1870 COHN, F. Ueber das Vorkommen von Kieselschwammnadeln in einem dichten grauen Kalkstein (*Jahresb. Schlesch. Gesell.*, vol. xlviii, pp. 63, 64).

Records the occurrence of hexactinellid and lithistid spicules from a well-boring at Inowraclaw. The rock is believed to be of Cretaceous age.

108. 1871 GEINITZ, H. B. Die Seeschwämme des unteren Quaders. Die Seeschwämme des mittleren und oberen Quaders (*Palæontographica* Bd. xx, 1 Th., pp. 1—41, Pls. 1—10).

The identity of the minute structure of fossil Sponges with lattice-shaped mesh (Gitterschwämme, A. Roemer) and recent hexactinellids is recognised, and the fossil forms with this structure are placed in the same group with the recent. Fossil Sponges with the so-called vermiculate mesh are regarded as probably of the same nature as recent lithistid Sponges, and placed in the same group. The doubtful *Spongites* is placed under the *Halisarcinæ*. The classification adopted by this author marks a great step in advance. A mistake was made, however, in placing all Sponges with vermiculate fibres under the Lithistidæ, since many of them are calcisponges.

109. 1871 HICKS, H. Descriptions of New Species of Fossils from the Longmynd Rocks of St. David's (*Quart. Journ. Geol. Soc.*, vol. 27, p. 401, Pl. XVI, figs. 14—20).

Describes some doubtful lines on rock surfaces as *Protospongia* (?) *major* and *P. (?) flabella*.

110. 1871 PHILLIPS, J. Geology of Oxford and of the valley of the Thames.

Gives a list of the Amorphozoa of the Cretaceous system, and figures some of the commoner Sponges from the Lower Greensand of Faringdon.

111. 1871 CARTER, H. J. On Fossil Sponge Spicules of the Greensand compared with those of existing species (*Ann. and Mag. Nat. Hist.*, 4 S., vol. vii, pp. 112—141, Pls. VII—X).

Very numerous forms of detached spicules from the Upper Greensand of Blackdown and Haldon are shown to correspond very closely with the spicules of recent tetractinellid, lithistid, and hexactinellid Sponges.

112. 1871 SIMONOWITSCH, S. Beiträge zur Kenntniss der Bryozoen des Essener Grünsandes (*Verh. d. nat. Ver. Jahrg.*, xxviii, 3 Folge, Bd. viii).

Places as Bryozoa, *Thalamopora cribrosa*, Goldf., sp., and *T. michelinii*, n. (pp. 27—34, Pl. 1, I, 2), now shown to be calcisponges and included in *Tremacystia*, Hinde.

113. 1872 HAECKEL, E. Die Kalkschwämme.

The author denies the existence of entire fossil calcisponges and states that the forms generally known as such have no relation to the group. Further, states that the delicate character of recent calcisponges renders it impossible that similar forms can have been preserved in the fossil state, though it is not improbable that their detached spicules may yet be recognised.



114. 1872 HOLL, H. B. Notes on Fossil Sponges (*Geol. Mag.*, vol. ix, pp. 309—315, 343—352).

Refers to the general characters of fossil Sponges, and points out the artificial nature of the classification of D'Orbigny and Fromentel. The following conclusions are given: (1) That the present state of fossil Sponges affords no certain indication of their condition during life, and (2) that in the differentiation of genera and species the same principles must be kept in view in fossil as in recent Sponges.

115. 1872 DEWALQUE, G. Un Spongiaire nouveau du système Eifélien (*Bull. Acad. Roy. de Belgique*, T. 34, pp. 23—26, Pl. 1).

Describes and figures a new species of *Astræospongia*.

116. 1872 POMEL, A. Paléontologie de la province d'Oran, 5 Fasci. (*Spongiaires*, pp. 1—256, 36 pls.).

The untenability of the theory of D'Orbigny and Fromentel that fossil Sponges are altogether distinct from recent forms is fully recognised. Pomel divides the class Spongiaires into two primary groups: (1) *Camptospongiaires*, in which the spicules when they exist are isolated and not organically attached together, and (2) *Petrospongiaires*, in which the skeleton is a continuous tissue of stony consistency. This latter group is again divided into *Dictyoscléroses*, which appears to be equivalent to hexactinellids, and *Psammoscléroses*, forms with skeletons of a granular or vermiform texture. In this latter order the author distinguishes two families, one with a calcareous and the other with a siliceous skeleton. As regards the skeleton of the *Dictyoscléroses*, or hexactinellid Sponges, Pomel maintains the same opinion as Roemer that the spicular tissue has in all cases originally been siliceous and that in the instances in which it is now calcareous the change has been produced by molecular displacement. Pomel thus appears to have been the first to recognise the substitution of calcite in the place of the original silica in the skeleton of fossil Sponges. The smaller subdivisions of Pomel are based upon the position and character of the so-called 'Proctides,' and most of the genera of previous authors are split up on very insufficient grounds. Numerous genera and species, apparently both of hexactinellid and lithistid Sponges, are described and figured, but their spicular characters are not referred to.

117. 1872 MURCHISON, R. I. Siluria, 5th ed.

In the table drawn up by Mr. Etheridge showing the vertical range of the Silurian Fossils of Britain, there are enumerated (p. 509) seventeen species of Amorphozoa, but ten of these are either doubtful forms or belong to other groups.

118. 1872 SCHLÜTER, C. A. Ueber die Spongitarie-Baenke der oberen Quadraten und unteren Mukronaten-Schichten des Münsterlandes (*Sitzungsb. d. Niederrhein. Gesells.*, pp. 1—38, Pl. 1).

Describes in detail the characters and stratigraphical distribution of the various Sponges in these beds, and constitutes two new genera of hexactinellid Sponges, *Lepidospongia* and *Becksia*.

119. 1873 SALTER, J. W. Catalogue of Cambrian and Silurian Fossils in Geol. Museum, Cambridge.

The forms referred to Sponges are placed under Amorphozoa. It is stated "that *Stromatopora*, *Coscinopora*, *Cnemidium*, *Verticillopora*, *Stellispongia*, &c., are examples of very solid calcareous Sponges. *Ischadites*, *Sphærospongia*, *Amphispongia*, and other Silurian forms, are supposed to be distantly allied to the living *Grantia*." *Ischadites Kænigii* is figured erroneously with stem and roots.

120. 1873 CARTER, H. J. On the Hexactinellidæ and Lithistidæ (*Ann. and Mag. Nat. Hist.*, vol. xii, p. 349, 437, Pls. xiii, xvii).

Refers in detail to the spicular structure of these groups as shown in existing species, and comparisons are made in one or two cases with fossil forms as well.

121. 1873 FISHER, O. On the Phosphatic Nodules of the Cretaceous Rocks of Cambridgeshire.

Refers to their constitution, and regards many of them as having originally been Sponges.

122. 1873 SOLLAS, W. J. On the Ventriculitæ of the Cambridge Upper Greensand (*Quart. Journ. Geol. Soc.*, vol. xxix, pp. 63—70, Pl. VI).

Describes the minute structure of the Ventriculite skeleton, which is stated to consist of the "regular anastomosis of a number of hexaradiate elements, each of which consists of six radial fibres, apparently tubular, diverging from a common centre, at right angles to each other." The constitution of these fibres is not stated, but the author mentions that he failed to find spicules, either in silicified or phosphatised Ventriculites. The silicified Ventriculites are regarded as instances of the silicification of highly decomposable animal matter, and the phosphatic Ventriculites 'are striking examples of the phosphatisation of soft-bodied animals.' The presence of siliceous *Xanthidia* and *Polycystina* in the Coprolites is adduced as 'an argument against regarding the Ventriculites as having originally had a siliceous skeleton which had subsequently been replaced by phosphate of lime.'

123. 1874 RUTOT, A. Note sur la découverte de deux Spongiaires de l'Étage Bruxellien des environs de Bruxelles (*Ann. de la Société Malacologique de Belgique*, Tome ix, pp. 1—14, Pl. 3).

Numerous siliceous accretions occur in these Tertiary beds, which are largely composed of the detached spicules of siliceous tetractinellid Sponges. These accretions are erroneously regarded as definite Sponges, and on them two species are based, *Stelletta discoidea* and *Dysidea tubulata*.

124. 1874 WYVILLE-THOMSON, C. The Depths of the Sea.

The essential similarity in the minute skeletal structures of recent hexactinellid Sponges and of the *Ventriculites* of Toulmin Smith, is pointed out. An erroneous comparison is made between the general structure of *Cœlosphæra tubifera*, a recent monactinellid Sponge, and *Choanites*, a fossil lithistid, the body-canals of this latter form being mistaken for tube-like processes, present in the existing Sponge.

125. 1874 DAVEY, E. C. The Sponge-Gravel Beds at Coxwell near Faringdon.

A general description is given of the deposit, and reference made to the Sponges with which it is filled; they are placed in the obsolete genera *Manon*, *Tragos*, &c.

126. 1874 MEYN, L. Silurische Schwämme und deren eigenthümliche Verbreitung, ein Beitrag zur Kunde der Geschiebe (*Zeits. d. deutsch. geol. Gesell.*, vol. xxvi, pp. 41—58).

Treats of the state of preservation and mineral condition of the fossil Sponges in the Drift deposits of the Island of Sylt.

127. 1875 GÜMBEL, C. W. Beiträge zur Kenntniss der Organisation und systematischen Stellung von Receptaculites (*Abh. der k. bayer. Akad. der Wiss.*, II Cl., Bd. xii, 1 Ab., pp. 169—215, Pl. A).

A minute detailed description of the characters of the genus is given, its thick inner and outer walls are stated to consist of individual plates held in position by intervening pillars, and a branching canal-system is also present. The genus is included in the Foraminifera in close relationship to *Dactylopora*. The genus *Ischadites* is regarded as similar generically to *Receptaculites*, and *Protospongia* is also a related form.

128. 1874—75 BARROIS, CH. Sur la Philogénie des Éponges (*Ann. Soc. Géol. Nord*, pp. 71—73).

Refers to the presence of lithistid spicules in Devonian Sponges, and the abundant development of the hexactinellidæ in the Chalk, and of the Corticatæ

in Tertiary strata. States that Haeckel is wrong in denying the existence of calcisponges in the fossil state. Regards *Astræospongium* as a calcisponge.

129. 1875 WRIGHT, JOSEPH. A List of the Cretaceous Microzoa of the North of Ireland (*Belfast Nat. Hist. Field Club Report* for year 1873-4, n. s., vol. i, pp. 72-80, Pls. II, III).

Amongst these are numerous detached siliceous spicules, obtained from the interior of flints from the Upper Chalk, which were compared by Dr. Bowerbank to the spicules of *Tethea*, *Geodia*, *Dactylocalyx*, and other siliceo-fibrous Sponges.

130. 1875 PILLET, M. L., ET FROMENTEL, M. E. Description Géologique et Paléontologique de la Colline de Lémenc sur Chambéry.

Several species, mostly calcisponges, are described and figured, but no reference is made to their minute structures.

131. 1875 BILLINGS, E. On some new or little-known Fossils from the Silurian and Devonian Rocks of Ontario (*Canadian Nat. and Geologist*, n. s., vol. vii, p. 230, figs. 1, 2).

The genus *Aulocopina* is defined, and its form and canal-structure is stated to resemble *Aulocopium*, Oswald. The spicular characters are unknown.

132. 1876 ZITTEL, K. A. Untersuchungen über fossile Spongien. Protokoll der Sitzung der deutschen geologischen Gesellschaft zu Jena, vom 14 August, 1876 (*Zeitsch. d. deutsch. geol. Gesellschaft*, Bd. 23, 1876, p. 629).

Prof. Zittel states that the majority of the so-called Petrosponges have undergone great alteration in their mineral structures in the course of fossilization, that the original silica of their skeletons has been replaced by calcite, and that owing to the delicacy of their siliceous fibres and the presence of axial canals, they become readily susceptible to the solvent influences of alkaline waters. A great part of the Petrosponges is stated to belong to the same group as the existing hexactinellids and lithistids, whilst in another division the fibres consisted originally of calcite.

133. 1876 ZITTELL, K. A. Untersuchung fossiler Hexactinelliden (*Neues Jahrbuch für Min.*, p. 286).

Announces in anticipation of his monograph on *Cœloptychium* the resemblance between the structure of this genus and *Ventriculites*, and states that the skeleton consists of amalgamated six-rayed spicules with a hollow octahedral node in the centre of each.

134. 1876 KAYSER, E. Beiträge zur Geologie und Palaeontologie der argentinischen Republik (*Palæontographica*, Lief. iii, p. 22).

Refers generally to the fossil Sponges met with, and figures a small form, subsequently named by Zittel *Protachilleum Kayseri*.

135. 1876 MARCK, v. der. Neue Beiträge zur Kenntniss der fossilen Fische und andern Thierreste aus der jüngsten Kreide Westfalens (*Palæontographica*, Bd. xxii, p. 68, Pl. ii, fig. 10).

Describes as a new genus of Sponges, *Glenodictyum*, a fibrous body growing in the form of a hexagonal mesh-work. The minute structure cannot be recognised and the character of the fossil is very problematical.

136. 1876 SOLLAS, W. J. On *Eubrochus clausus*, a vitreo-hexactinellid Sponge from the Cambridge Coprolite Bed (*Geol. Mag.*, pp. 398—403, Pl. XIV).

Describes the form and compares its external structure with that of the existing genus *Farrea*, but the fossil Sponge is stated to possess an interior skeleton as well as an outer membrane.

137. 1876 ZITTEL, K. A. Ueber Coeloptychium. Ein Beitrag zur Kenntniss der Organisation fossiler Spongien (*Abh. der k. bayer. Akad. der Wiss.*, II Cl., xii Bd., iii Ab., pp. 1—80, Pls. I—VII).

An elaborate monograph on the general structure, the canal-system, and skeletal mesh of the Sponges of this genus. The nodes of the spicules are compared with those of the living genus *Myliusia*. The body of the Sponge is shown to consist of thin walls of spicular tissue disposed in radiating folds, which are enclosed in a cribriform dermal layer. Numerous detached spicules in the interior of these Sponges are erroneously regarded as belonging to their skeletal structures, but Zittel subsequently pointed out that their presence was accidental.

138. 1876 ARMSTRONG, YOUNG, and ROBERTSON. Catalogue of the Western Scottish Fossils.

From the Upper Girvan series *Ischadites Koenigii* is recorded, and *Hyalonema parallelum* and *Acanthospongia Smithii* from the Carboniferous of Ayrshire.

139. 1877 CARTER, H. J. Note on the Tubulations sableuses of the Étage Bruxellien in the environs of Brussels (*Ann. and Mag. Nat. Hist.*, S. 4, vol. xix, pp. 382—393, Pl. 18).

The forms described by Rutot as Sponges are regarded by Carter as the tubes of a new type of Annelids. The siliceous spicules associated with them

are classified, and some are shown to be similar to those described by Carter from Greensand strata.

140. 1877 CARTER, H. J. On a Fossil species of Sarcohexactinellid Sponge allied to *Hyalonema* (*Ann. and Mag. Nat. Hist.*, S. 4, vol. xx, p. 176).

A provisional notice of the presence of spicules of this group of Sponges in Carboniferous strata.

141. 1877 YOUNG, J., and YOUNG, J. On a Carboniferous *Hyalonema* and other Sponges from Ayrshire (*Ann. and Mag. Nat. Hist.*, S. 4, vol. xx, pp. 425—432, Pls. XIV, XV).

Numerous detached hexactinellid spicules, with others of anomalous form, and portions of elongated spicular rods, are regarded as belonging to a Sponge of the existing genus *Hyalonema*. Also a fibrous Sponge in which no spicules could be recognised is placed in a new genus, *Haplistion*.

142. 1877 TRAUTSCHOLD, H. Ueber Kreidefossilien Russlands (*Bull. de la Soc. imp. des nat. de Moscou*, vol. 52, p. 339, Pl. vi).

Describes various species which are placed in the genera *Cupulispongia*, *Porospongia*, and *Placuntarion*. Nothing is stated of their minute structures.

143. 1877 ZITTEL, K. A. Studien über fossile Spongien. 1 Abtheil., Hexactinellidæ (*Abhandl. d. k. bayer. Akad. der Wissenschaften*, II Cl., xiii Bd., pp. 1—63, Pls. I—IV).

Describes the systematic position, the condition of preservation, the characters, and the classification of fossil hexactinellids. Their skeletal structures are shown to possess the closest relationship to those of recent hexactinellids from the depths of the ocean, and they are very distinctly marked off from the Lithistids. Two main divisions are constituted (1) *Lyssakina*, in which the skeletal spicules are, as a rule, detached from each other, and only held in position by the sarcode; and (2) *Dictyonina*, in which the skeletal spicules are fused together in a regular manner, so as to form a connected lattice-like mesh with cubical or polyhedral interspaces. In this latter division are included the following families; *Astylospongiidæ*, *Euretidæ*, *Coscinoporidæ*, *Mellitionidæ*, *Ventriculitidæ*, *Staurodermidæ*, *Mæandrospongiæ*, *Callodictyonidæ*, and *Cæloptychidæ*, whilst in the *Lyssakina* are included *Monakidæ*, Marshall; *Pleonakidæ*, Mars.; and *Pollakidæ*, Mars. Numerous new genera are proposed and diagnoses of them given.

144. 1877 ZITTEL, K. A. Beiträge zur Systematik der fossilen Spongien (Erster Th.) *Neues Jahrbuch*, pp. 337—378, Pls. II—V).

For the most part a reprint from the "Studien" referred to above.

145. 1877 ZITTEL, K. A. Studies on Fossil Sponges, I, Hexactinellida (*Annals and Mag. Nat. Hist.*, 4 S., vol. xx, pp. 257—273, 405—424, 501—517).

Translated by W. S. Dallas from the "Studien" in 'Abhand. d. k. bayer. Akad. der Wiss.,' II Cl., Bd. XIII.

146. 1877 ZITTEL, K. A. Untersuchungen über fossile Spongien (*Neues Jahrbuch*, pp. 705—709).

A short notice and criticism of the first part of vol. v of 'Quenstedt's Petrefaktenkunde.'

147. 1877 SOLLAS, W. J. On *Pharetrospongia Strahani*, a fossil Holorhaphidote Sponge from the Cambridge Coprolite Bed (*Quart. Journ. Geol. Soc.*, vol. xxxiii, pp. 242—255, Pl. xi).

Gives a minute description of its structural characters; it is composed of anastomosing fibres, which consist of minute acerate spicules, closely arranged, generally parallel to one another. The forms are now nearly entirely calcareous, but in some cases a thin external film of the fibre with some of the spicules is siliceous. The Sponge is regarded as having originally been siliceous, and it is placed in the family *Renierida*.

148. 1877. SOLLAS, W. J. On the Structure and Affinities of the genus *Siphonia* (*Quart Journ. Geol. Soc.*, pp. 790—835, Pls. xxv, xxvi).

The minute structure of the skeleton is fully described; it is stated to consist of quadriradiate spicules with four diverging arms, bifurcating near their extremities and terminating in a number of rounded apophyses with intervening concavities. This structure is compared with that of the existing lithistid *Discodermia*. Details are given of the mineral changes produced by fossilization, including that of the replacement of the original silica by calcic carbonate, which had been already noted by Pomel and Zittel. *Siphonia* is placed in the family *Pachastrellidæ* and the order *Holorhaphidota*, Carter.

149. 1877 SOLLAS, W. J. On *Stauronema*, a new genus of Fossil Hexactinellid Sponges, with a description of its two species *S. Carteri* and *S. lobata* (*Ann. and Mag. Nat. Hist.*, S. 4, vol. xix, pp. 1—25, Pls. I—V).

Describes a fan-shaped Sponge with a very robust spicular mesh, the canals in which are stated to pass ordinarily from one node to another, and thus to differ from recent hexactinellids. The wall of the Sponge forms a thin, so-called oscular plate, which is overgrown at its base by a thick mass of irregular spicular tissue.

150. 1877 MARTIN, K. Untersuchungen über die Organization von *Astylospongia*, F. Roemer (*Archiv des Ver. der Freunde der Naturges. in Mecklenburg, Jahrg. xxxi*, pp. 1—32, Pl. 1).

Gives a lucid description of the canal-system, and points out that the number of the rays given off from each of the spicular nodes of the skeleton is not definitely six, as stated by Roemer, but that it varies from six to nine, and their arrangement is also without definite order; consequently the relationship between this genus and typical hexactinellids is somewhat doubtful.

151. 1876–78 QUENSTEDT, F. A. Petrefactenkunde Deutschlands, Bd. V. Korallen (Schwämme), pp. 1—612, with 28 folio plates.

No systematic arrangement of fossil Sponges is attempted; they are placed as a group under Corals. The descriptions are of a desultory character, and treat rather of individual peculiarities than of specific or generic features, and the employment of microscopic investigation is deprecated, as leading to erroneous ideas. The author gives new terms to genera and species, which in his opinion will indicate their characters, and arbitrarily rejects those previously applied to them. The main value of the work consists in its excellent illustrations of the external features of most of the known forms of fossil Sponges.

152. 1878 CARTER, H. J. Mr. James Thomson's Fossil Sponges from the Carboniferous System of the South-West of Scotland (*Ann. and Mag. Nat. Hist.*, S. 5, vol. i, pp. 128—143, Pls. IX, X).

Treats first of the character of the spicules in *Hyalonema Smithii*; then points out that, owing to the fragile nature of the skeleton of calcisponges, it is almost impossible that *Pharetrospongia*, Sollas, could ever have belonged to this group. Further describes as a new siliceous Sponge *Pulvillus Thomsoni*, which is placed in the *Renierida*, the form is now calcareous; and *Rhaphidistia vermiculata* as a laminiform Sponge parasitic on *Hydractinia*.

153. 1878 v. MATYASOWSKY, J. Ein fossiler Spongit aus dem Karpathensandsteine von Kis-Lipnik im Saroser comitate (*Glenodictyum carpathicum*) (*Fermesyetragzi füsetek*, vol. ii, pt. 4, 1878. *Verh. der k. k. geolog. Reichsan. Wien*, p. 405).

Describes and figures a specimen belonging to the problematical genus, *Glenodictyum*, Marek.

154. 1878 YOUNG, J. T. On the occurrence of a Fresh-water Sponge in the Purbeck Limestone (*Geol. Mag.*, n. s., vol. v, p. 220).

Describes and figures detached acerate microspined spicules in chert of fresh-water origin, which are referred to *Spongilla purbeckensis*.



155. 1878 SOLLAS, W. J. On the Structure and Affinities of the Genus *Catagma* (*Ann. and Mag. Nat. Hist.*, S. 5, vol. 2, pp. 353—364, Pl. XIV).

Describes the minute structure of some fibrous calcisponges from the Lower Greensand of Faringdon, which is stated to consist of two kinds of spicules, one kind uniaxial, arranged longitudinally in the exterior third of the fibre, the other kind multiradiate (three- or four-rayed), three of the rays occupying the interior or core of the fibre, the fourth directed outwardly and echinating the exterior of the fibre. The Sponges, in opposition to the views of Zittel, are regarded as siliceous, and placed as a new sub-family, the *Catagnidæ*, in the order *Rhaphidonemata*, Carter.

156. 1878 TRAUTSCHOLD. Ueber *Camerospongia Auerbachi*, Eichwald (*Zeitschr. d. deutsch. Geol. Gesell.*, Bd. 30, pp. 225—228, Pl. IX).

Shows that this Sponge properly belongs to the genus *Cœloptychium*, Goldf.

157. 1878 CARTER, H. J. Emendatory description of *Purisiphonia Clarkei*, Bowerb., a Hexactinellid Fossil Sponge from N. W. Australia (*Ann. and Mag. Nat. Hist.*, S. 5, vol. i, p. 376).

Gives details of the structure and of the form of the flesh-spicules.

158. 1878 BIGSBY, J. J. Thesaurus Devonico-Carboniferus.

Under *Amorphozoa* there are twenty-five species enumerated, but not more than five or six of these are true fossil Sponges.

159. 1878 MARTIN, K. Niederländische und nordwest-deutsche Sedimenter-Geschiebe, pp. 63—68, Pl. I.

Describes a new species, *Aulocopium variable*, and as a new genus and species *Silurispongia conus*, but the spicular structure of this form is unknown, and the generic characters are, therefore, of little value.

160. 1878 WALLACE, S. On the Geodes of the Keokuk Formation (*American Journ. Science*, S. 3, vol. xv, pp. 366—370).

These bodies are believed to be Sponges, and formed into a new genus, named *Biopalla*, including numerous species. No figures are given, and the evidence brought forward is altogether insufficient to establish their alleged origin.

161. 1878 ETHERIDGE, R., Junr. Palæontological Notes (*Geol. Mag.*, Dec., ii, vol. V, p. 119).

Records fresh localities in the East of Scotland where the anchoring rope of *Hyalonema parallelum* = *Hyalostelia Smithii*, Young and Young occurs, and notices a more delicate form, proposed to be named *H. Youngi*, but which is probably the true *H. parallelum*, of M'Coy.

162. 1878 ZITTEL, K. A. Zur Stammes-Geschichte der Spongien (*Festschrift zum Jubiläum des Prof. von Siebold*, pp. 1—20).

Refers to the recent investigations into the embryology of living Sponges as proving their Metazoal character. Sponges generally are ranked under seven orders, *Myxospongiæ*, *Ceraospongiæ*, *Monactinellidæ*, *Tetractinellidæ*, *Lithistidæ*, *Hexactinellidæ*, and *Calcispongiæ*. The geological history of Sponges is given, and it is shown that even in the Palæozoic period six of the main orders were present, and even then distinctly marked off from each other, so that there is no palæontological evidence to show the original stock from which they have descended.

163. 1878 ZITTEL, K. A. Ueber Jura-Spongien (*Neues Jahrbuch*, pp. 58—62).

Reference is made to the descriptions and figures of Jurassic hexactinellid Sponges in Heft 2 of vol. v of Quenstedt's *Petrefaktenkunde*, and they are compared with those described by Zittel in the "Studien," pt. 1.

164. 1878 ZITTEL, K. A. Studien über fossile Spongien, 2te Abtheilung, Lithistidæ (*Abh. der k. bayer. Akad. der Wiss.*, II Cl., xiii Bd., pp. 67—154, Pls. I—X).

Shows that a large group of fossil Sponges possessed the same spicular structures as the recent Lithistids of Oscar Schmidt. Their spicular characters are described in detail, and the order is divided according to the character of their elementary spicules into the following four families, *Rhizomorina*, *Megamorina*, *Anomocladina*, and *Tetracladina*. In each of these families new genera are proposed, based mainly on the character of the canal-system, and modifications of their dermal surfaces. The structural characters are fully illustrated.

165. 1878 ZITTEL, K. A. Beiträge zur Systematik der fossilen Spongien. 2te. Th. Lithistiden (*Neues Jahrbuch*, pp. 561—618, Pls. VII—X).

A reprint from the "Studien" in 'Abh. d. k. bayer. Akad. d. Wiss.,' II Cl., xiii Bd.

166. 1878 ZITTEL, K. A. Studies on Fossil Sponges, II, Lithistidæ (*Ann. and Mag. Nat. Hist.*, S. 5, vol. ii, pp. 113—135, 235—248, 324—341, 385—394, 467—482, Pl. VIII).

Translated by W. S. Dallas from the "Studien" in 'Abh. d. k. bayer. Akad. der Wiss.,' II Cl., Bd. xiii, Abth i, pp. 67—154.

167. 1878 ZITTEL, K. A. Studien über fossile Spongien, 3tte Abtheilung, Monactinellidæ, Tetractinellidæ, und Calcispongiæ (*Abh. der k. bayer. Akad. der Wiss.*, II Cl., xiii Bd., II Ab., pp. 93—138, Pls. XI—XII).

Fossil Monactinellid Sponges are shown to be a small and unimportant

group. Two new genera are proposed, *Opetionella* and *Scoliorhaphis*. The Tetractinellidæ are likewise rarely found as entire Sponges, though their spicules occur even in Carboniferous Rocks. A new species of *Pachastrella* is described, and a new genus *Tethyopsis*. Fossil calcisponges are shown to be very numerous. The views of Haeckel and Carter that Sponges of this group could not be preserved as fossils are discussed and regarded as erroneous. With the exception of a single form, *Protosycon*, fossil calcisponges belong to a distinct family, characterised by a skeletal structure of anastomosing fibres. These fibres are built up of minute uniaxial and three-rayed spicules, comparable to those of existing calcisponges. It is shown that these fossils are not, as stated by Carter and Sollas, siliceous Sponges which have been replaced by calcite. In the new family, *Pharetrones*, several new genera are introduced, as well as many genera of previous authors, including *Pharetropsongia*, Sollas.

168. 1878 ZITTEL, K. A. Handbuch der Palaeontologie, Bd. i, II Lief.

Descriptions are given of the various groups of fossil Sponges, similar to those in the "Studien." Diagnoses of all the genera are given, and illustrations of the typical forms. The genus *Hyalostelia* is proposed to include *Hyalonema Smithii*, Young.

169. 1878 SOLLAS, W. J. Notes on the Ventriculites of the Chalk (*Dixon's Geology of Sussex*, New Edition, pp. 448—455, Pls. XLVI—LI).

Describes the spicular structure and other characters of the genus; the former is compared with the structure of the recent hexactinellid, *Myliusia Grayi*.

170. 1879 ZITTEL, K. A. Beiträge zur Systematik der fossilen Spongien. Dritter Th., *Neues Jahrbuch*, pp. 1—40, Pls. I, II.

Mostly a reprint from Abhand. der k. bayer. Akad. der Wiss., II Cl., xiii Bd.

171. 1879 ZITTEL, K. A. Studies on Fossil Sponges, III, IV, V, Monactinellidæ, Tetractinellidæ, and Calcispongiæ (*Ann. and Mag. Nat. Hist.*, S. 5, vol. iii, pp. 304—312, 364—379; also vol. iv, pp. 61—73, 120—135).

Translated by W. S. Dallas from the "Studien," Dritte Abth.

172. 1879 NICHOLSON, H. A. Manual of Palaeontology, 2nd Edition.

The first part of the volume was written before the works of Zittel were fully published, and consequently it is mainly interesting as indicating the generally received views held at the time on fossil Sponges. *Astræospongia*, *Amphispongia*, and provisionally *Stromatopora* and *Archeocyathus* are included with calcisponges. Zittel's classification is adopted for fossil siliceous

Sponges. *Receptaculites*, *Ischadites*, and *Tetragonis* are regarded as aberrant types of Foraminifera.

173. 1879 SINZOW, J. On Calcareous Sponges from the Government of Saratow (Russian) (*Trans. (Zapiski) New Russian Nat. Hist. Soc.*, vol. vi, pp. 1—40).

174. 1879 CARTER, H. J. On *Holasterella*, a Fossil Sponge of the Carboniferous Era, &c. (*Ann. and Mag. Nat. Hist.*, S. 5, vol. iii, pp. 141—150, Pl. XXI).

Describes a club-shaped Sponge, which is stated to be built up of stellate spicules, with normally twelve rays or arms. The genus is placed in the Suberitida, under *Holorhaphidota*.

175. 1879 MAZZETTI e MANZONI. Le Spugne fossile di Montese (*Atti. de la Soc. Toscani dei sci. nat.*, vol. iv, p. 57, 2 pls.).

The existence is shown of hexactinellid and lithistid Sponges in the Montese marls, which are of Miocene age. Their skeletal structures have been replaced by calcite. The species are not determined.

176. 1879 HANNAY, J. B. On Siliceous Fossilisation (*Mem. of the Lit. and Phil. Soc. of Manchester*, S. 3, vol. vi, p. 234).

Describes the present state of preservation of the spicules of *Hyalonema Smithii* and traces the various changes in the silica arising from fossilisation.

177. 1879 WOECKENER, H. Ueber das Vorkommen von Spongien im Hilssandstein. Zusatz zu vorstehendem Aufsatz, von Herrn Zittel (*Zeitsch d. deutsch. geol. Gesell.*, Bd. 31, pp. 663—667).

Large, irregular, siliceous masses, numerous in the Sandstone, are regarded as siliceous Sponges, but Zittel points out that these are not Sponges, though they result from the solution of the detached spicules of Sponges, of which negative casts remain. The rock is therefore a Sponge deposit mostly of monactinellid spicules. Zittel records similar deposits in the Upper Lias of the Tyrol, and in the Rhætic of Upper Bavaria, as well as in the Cretaceous strata of Westphalia.

178. 1879 DUNCAN, P. M. On some Spheroidal Lithistid Spongida from the Upper Silurian Formation of New Brunswick (*Ann. and Mag. Nat. Hist.*, S. 3, vol. iv., pp. 84—91, Pl. IX).

The structure of a new genus, *Hindia*, is described and figured. It is stated to be built up of tripod-shaped spicules, but the sponge is regarded as having originally been composed of carbonate of lime.

179. 1880 SOLLAS, W. J. On the Structure and Affinities of the genus *Protospongia* (*Quart. Journ. Geol. Soc.*, vol. xxxvi, pp. 362—367, figs. 1, 2).

Describes the form and arrangement of the spicules; they are regarded as separate, and not united either by envelopment in a common coating or by ankylosis; the Sponge is consequently placed in the Lyssakina division of Zittel.

180. 1880 SOLLAS, W. J. On the Flint Nodules of the Trimmingham Chalk (*Annals and Mag. Nat. Hist.*, vol. vi, pp. 384—395, 437—461, Pls. XIX, XX).

Describes various forms of detached spicules of Tetractinellid and Lithistid Sponges obtained from the soft chalk surrounding the flints. The spicules are for the most part placed in new genera and species.

181. 1880 GÜMBEL, C. W. Spongien-Nadeln im Flysch. (*Verh. d. k. k. geol. Reichsan. Wien*, pp. 213—215).

States that in many localities the "Flysch" of the North-eastern Swiss and Bavarian Alps is largely composed of detached Sponge-spicules; they are invariably present in a peculiar, fine-grained, siliceous limestone. Notices also, that rocks of Neocomian age from Rossfeld, and certain strata of Lias age from Algäu and elsewhere are similarly composed of an aggregate of Sponge-spicules.

182. 1880 CARTER, H. J. On Fossil Sponge-Spicules from the Carboniferous strata of Ben Bulbin near Sligo (*Ann. and Mag. Nat. Hist.*, vol. vi, pp. 209—214, Pl. XIV, B).

Describes detached spicules of *Reniera* and of a lithistid Sponge, and also hexactinellid spicules with bifurcate and spiral rays, which are referred to *Holasterella*.

183. 1880 STEINMANN, G. Mikroskopischen Thierreste aus dem deutschen Kohlenkalk (*Zeitsch. d. deutschen geol. Gesell.*, Bd. 32, p. 395, Pl. XIX).

Describes and figures an umbrella-shaped spicule from the Carboniferous Limestone of Ratingen near Dusseldorf, under *Hyalostelia Smithii*.

184. 1880 HINDE, G. J. Fossil Sponge-Spicules from the Upper Chalk, pp. 1—83, Pls. I—V.

Describes and figures a great variety of detached spicules, obtained from the interior of a flint nodule. These are referred to different genera of monactinellid, tetractinellid, lithistid, and hexactinellid Sponges.

185. 1880 ROEMER, FERD. *Lethæa geognostica* (1 Th., *Lethæa palæozoica*).

The family *Receptaculitidae* is placed provisionally with Foraminifera, and *Dictyophyton* is regarded as similar to *Tetragonis*. The following genera are described as true palæozoic Sponges, *Astylospongia*, *Palæomanon*, *Prota-*

*chilleum*, *Aulocopium*, *Astræospongia*, *Protospongia*, and *Acanthospongia*; and references are given to the species described. *Brachiospongia*, *Acestra*, *Bothroconus*, and some other genera are regarded as doubtful.

186. 1881 SOLLAS, W. J. On *Astroconia Granti*, a new Lyssakine Hexactinellid from the Silurian Formation of Canada (*Quart. Journ. Geol. Soc.*, vol. xxxvii, pp. 254—260, figs. 1—11).

Describes various forms of detached acerate and hexactinellid spicules, which are referred to this new genus and species.

187. 1881 SOLLAS, W. J. Note on the Occurrence of Sponge-Spicules in Chert from the Carboniferous Limestone of Ireland (*Ann. and Mag. Nat. Hist.*, vol. vii, pp. 141—143, fig. 1).

Mentions the occurrence, in some cases in great abundance, of spicules in microscopic sections of chert, which had been described by Prof. Hull as of inorganic origin.

188. 1881 WHITFIELD, R. P. Observations on the Structure of Dictyophyton and its Affinities with certain Sponges (*American Journ. of Science*, vol. xxii, pp. 53, 132).

The structure of this organism, which had been referred by Hall to Algæ, is compared to that of the recent *Euplectella*, and it is supposed to have consisted of siliceous fibres, although positive evidence for this is at present wanting.

In a subsequent note an example of *Uphantenia* is described, in which the spicules forming the longitudinal and transverse bundles are now preserved in the condition of pyrite, and the rectangular spaces between the bundles are also covered with a thin film of the same substance.

189. 1880 NICHOLSON and ETHERIDGE, Junr. A Monograph of the Silurian Fossils of the Girvan District.

A description is given of *Ischadites Kænigii*, Murch.; its systematic position is regarded as doubtful; the siliceous rope of a Sponge is described under the name of *Hyalonema* (?) *Girvanense* (p. 239, Pl. xix, figs. 1, 1 b).

190. 1881 WHITFIELD, R. P. Remarks on Dictyophyton and descriptions of new species of allied forms from the Keokuk Beds at Crawfordsville, Indiana (Bulletin No. 1, *American Mus. Nat. Hist.*, p. 10, Pls. 3, 4).

Refers to the different names applied to this genus from time to time, and gives detailed descriptions of species of *Uphantenia* and *Dictyophyton*. The structure is stated to consist of longitudinal and transverse fibres or threads, formed of bundles of cylindrical spicula.

191. 1881 WALCOTT, C. D. On the Nature of Cyathophycus (*Amer. Journ. Science*, vol. 22, p. 394).

Its structure is stated to consist of narrow bands forming a horizontal and a perpendicular series, which cross each other at right angles. The bands are composed of threadlike spicula, now of pyrites. Two species are described. No reference is made to the form of the individual spicules beyond that they are threadlike.

192. 1881 STEINMANN, G. Ueber *Protetractis Linki*, n. f. eine Lithistide des Malmes (*Neues Jahrbuch*, Bd. ii, pp. 154—163, Pl. IX).

Describes a lithistid in which there is considerable variety in the form of the skeletal spicules. It is regarded as a genuine Tetracteladine. The author also refers the Silurian genus *Aulocopium* to the same family.

193. 1882 HINDE, G. J. Notes on Fossil Calcispongiae, with descriptions of new species (*Ann. and Mag. Nat. Hist.*, vol. x, pp. 185—205, Pls. X—XII).

Records the discovery in fossil *Pharetrones*, from the Upper Greensand, of three- and four-rayed spicules, which can be detached from the matrix, and are clearly identical in form with those of recent calcisponges. Some of them also occupy a similar relative position on the dermal surface of the Sponge. A specialised three-rayed spicule, in the shape of a tuning-fork, is present in the fossil genus *Sestrostomella*; it closely resembles a spicule in an existing Australian calcisponge. These facts clearly establish that the *Pharetrones* are, as Zittel claimed them to be, true calcisponges.

194. 1882 STEINMANN, G. Pharetronen-Studien (*Neues Jahrbuch*, Bd. ii, pp. 139—191, Pls. VI—IX).

This paper, which appeared almost simultaneously with that by Hinde mentioned above, contains the results of the author's five years study of the group. The *Pharetrones* are regarded as having been originally calcareous, their spicular elements are stated not to resemble those of recent calcisponges, since, amongst other reasons, no axial canals can be detected in them, and the recent spicules are stated to be so delicate as readily to melt in distilled water in a few seconds. Their structures are finally compared to those of *Aleyonaria*. Subsequent investigations have shown that the author's theories respecting the group are altogether erroneous.

195. 1882 ZITTEL, K. A. Notizen über fossile Spongien (*Neues Jahrb.*, ii Bd., p. 203).

Confirms Hinde's observations on the spicular structure of *Corynella* and other *Pharetrones*, and regards their character as calcisponges to be fully

proved. Regards *Protospongia* and *Dictyophyton* as belonging to dictyonine hexactinellids.

196. 1882 MUNIER-CHALMAS. Barroisia, n. g. des Eponges (*Bulletin Soc. Géol. de France*, S. 3, vol. x, p. 425).

Proposes this name for what he states is the *Tubipora anastomosans*, Mant. No other characters, but those of the outer form, are given, and there is no reference to the description of *T. anastomosans*.

197. 1882 MANZONI, A. La struttura microscopica delle Spugne silicee del Miocene medio di Bologna e di Modena, pp. 1—24, Pls. I—VII.

Describes in detail the condition of preservation, and the structural characters of several species of hexactinellid and lithistid Sponges, which are placed under Zittel's classification. The forms are well illustrated.

198. 1882 DUNIKOWSKI, E. Die Spongien der unterliassischen Schichten von Schafberg bei Salzberg (*Denks. d. k. Akad. der Wiss. Wien*, Bd. 45, pp. 163—194, Pls. I—IV).

Describes and refers to different genera numerous detached spicules of monactinellid, tetractinellid, and lithistid Sponges, as well as portions of hexactinellid meshwork, which occur, heterogenously mingled together, in cherty limestones of Lower-Lias age.

199. 1883 KEEPING, W. The Fossils of the Neocomian Deposits of Upware and Brickhill.

Amongst these are twelve species of Sponges; one is referred to *Plocoscyphia*, and the others belong to the family *Pharetrones*. The author does not express a decided opinion as to the nature of these latter, though he rather favours the opinion of Prof. Sollas that they are siliceous Sponges which have been replaced by calcite.

200. 1883 KLEMM, E. Ueber alte und neue Ramispongien und andere verwandte Schwammformen aus der Geislinger Gegend (*Jahreshft. Ver. f. vaterl. Naturk. Württemb.*, vol. xxxix, pp. 243—308).

Describes numerous Sponges from the White Jura which are all included in the undefined genus *Ramispongia*, Quenst. They are stated to be mostly hexactinellids. The specific characters are based on outer form and are apparently of little scientific value. No figures given.

201. 1883 DUNIKOWSKI, E. Die Pharetronen aus dem Cenoman von Essen, und die Systematische Stellung der Pharetronen (*Palæontographica*, Bd. 29, pp. 283—323, Pls. XXXVII—XL).

Describes in detail the spicular structures and other characters of these forms, and concludes that not only are they fossil calcisponges, but that their



structure agrees so closely with that of the existing family of *Leucones*, Hæck., that they should properly be included in it. Further, regards the fibres of these Sponges as not original structures but of secondary origin, produced wholly by the process of fossilization. Refutes in detail the objections raised by Steinmann to their spongy nature, and fully confirms the previous results of Zittel and Hinde.

202. 1883 CARTER, H. J. Further Observations on the so-called 'Farrington Sponges' (Calcispongiæ, Zittel), followed by a description of an existing species of a like kind (*Ann. and Mag. Nat. Hist.*, S. 5, vol. xi, pp. 20—37, Pl. I).

Confirms the observations of Hinde on fossil calcisponges, and acknowledges that they are rightly referred to this group. Thinks, however, that *Pharetrospongia Strahani*, Sollas, and some species of *Stellispongia*, in which only acerate spicules have been detected, cannot be claimed as calcisponges, but that they are siliceous Sponges with their structures replaced by calcite. Describes a recent form, *Leucetta clathrata*, in which the fibres are solid, as in the *Pharetrones*.

203. 1883 CARTER, H. J. Spicules of Spongilla in the Diluvium of the Altmühl Valley, Bavaria (*Ann. and Mag. Nat. Hist.*, S. 5, vol. xii, pp. 329—333, Pl. XIV).

Detached spicules of the body-skeleton and of the gemmules are recognised as belonging to *Meyenia* (*Spongilla*) *erinacea*, Ehr.

204. 1883 CARTER, H. J. On the Microscopic Structure of thin slices of Fossil Calcispongiæ (*Ann. and Mag. Nat. Hist.*, S. 5, vol. xii, pp. 26—30).

Refers to projecting pin-like spicules on the surface of *Verticillites anastomosans*, Mant., and to the changes in the fossilization of Pharetrones.

205. 1883 SOLLAS, W. J. The Group Spongiæ (*Cassell's Natural History*, vol. vi, pp. 312—331, figures).

Refers nearly exclusively to recent Sponges and only the geological appearance of the fossil forms mentioned. States that no fossil Sponge unquestionably belonging to the Calcispongiæ has, up to this time, been described. The Monaxonidæ, on the evidence of Cliona borings, are concluded to have been in existence in early Palæozoic times; *Pharetrospongia Strahani* is said to be a large Renierine Sponge, the best preserved and most certainly demonstrated example yet known; the Lithistidæ are said to occur from the Upper Cambrian to the Tertiary, and the Hexactinellidæ from the Lower Cambrian upwards.

206. 1883 ROEMER, FERD. Notiz über die Gattung Dictyophyton (*Zeitsch. d. deutsch. Geol. Gesell.*, p. 704).

Points out the resemblance of *Tetragonis Eifeliensis* to the genus *Dictyophyton*, and describes as new, *Dictyophyton Gerolsteinense*, which appears to be only the interior of *Sphærospongia tessellata*, Phill. sp. The author doubts that these fossils can have been siliceous Sponges, since their siliceous skeletons would have been preserved, but thinks that probably they may have possessed skeletons of a horny character like the existing Gorgonias.

207. 1883 WALCOTT, C. D. Fossils of the Utica Slate (*Transactions of the Albany Institute*, vol. x). Paper stated to have been read March, 1879.

*Cyathophycus*, subsequently recognised as a Sponge, is here described, figured, and named as Algæ, of reticulate or plain structure, and consisting of hollow membranous fronds (p. 18, Pl. ii, figs. 16, 17).

208. 1883 LINCK, G. Zwei neue Spongiengattungen (*Neues Jahrb. für Min.*, II Bd., 1ster Heft, pp. 59—62, Pls. II, III).

In one genus, *Didymosphæra*, the skeletal spicules consist of twin nodes connected by a straight rod with axial canal, and there are from three to five rays given off from each node. This form is considered as the typical elementary spicule of the Anomocladina family. The spicules become modified so as to resemble those of the Rhizomorina family. The other genus has spicules of the Rhizomorina type; it is named *Polyrhizopora*.

209. 1883 BARROIS, C. Sur les Dictyospongidae des Psammities du Condroz (*Ann. de la Soc. Géol. du Nord*, T. xi, pp. 80—86, Pl. 1).

Describes and figures two species of *Dictyophyton* from the Upper Devonian of the Ardennes, and places them as dictyinine hexactinellids.

210. 1883 HINDE, G. J. Catalogue of the Fossil Sponges in the British Museum. pp. 1—248, Pls. I—XXXVIII.

Descriptions are given of the British species, and of new species from foreign localities, which are figured. The classification of Zittel is followed. The following new genera of monactinellids are proposed: *Climacospongia*, *Lasiocladia*, and *Acanthorhaphis*. The new genera of lithistids are *Placonella*, *Holodictyon*, *Pachypoterion*, *Nematinion*, *Bolospongia*, *Kalpinella*, *Thamnospongia*, *Pholidocladia*, *Phymaplectia*, and *Rhopalospongia*. The genus *Astylospongia* is placed provisionally in the Hexactinellida, but it is suggested that its minute structure resembles more closely that of the Anomocladine lithistid, *Cylindrophyma*. The new genera of hexactinellids are *Strephinia*, *Sestrodictyon*, *Sestrocladia*, *Placotrema*, *Cincliderma*, *Plectoderma*, *Porochonia*, and *Sclerokalia*. The following genera of calcisponges are introduced:

*Tremacystia*, *Inobolia*, *Trachysinia*, *Diaplectia*, and *Rhaphidonema*. The author maintains the view of Zittel that the Pharetrones are a distinct family from the existing Leucones, and regards their fibrous structures as original, and not, as stated by Dunikowski, produced merely by fossilization.

211. 1883 SOLLAS, W. J. Descriptions of Fossil Sponges from the Inferior Oolite, with a notice of some from the Great Oolite (*Quart. Journ. Geol. Soc.*, vol. xxxix, pp. 541—554, Pls. XX, XXI).

Describes as new genera of hexactinellid Sponges, *Emploca*, *Mastodictyum*, *Plectospyris*, and *Calathiscus*, also a new species *Leptophragma fragile*. A new species of lithistid, *Platychonia elegans*, and several species of Pharetrones, as well as a new genus *Thamnonema*, are also described.

212. 1883–84 POČTA, P. Beiträge zur Kenntniss der Spongien der böhmischen Kreideformation. I Ab., Hexactinellidæ, sep. cop., pp. 1—42, Pl. 3; II Ab., Lithistidæ, sep. cop., pp. 1—45, 2 Pls. (*Abhandlung. der Königl. böhm. Gesell. der Wiss.*, vi Folge, 12 Bd.).

These memoirs give the results of a thorough investigation into the minute structures and other characters of the Sponges from the Cretaceous strata of Bohemia, the superficial characters of many of which had already appeared in the works of Reuss. Zittel's classification is adopted. In addition to many new species of existing genera, the following new genera of hexactinellids are proposed: *Petalope*, *Synaulia*, *Lopanella*, *Botroclonium*, and *Cyrtobolia*. The only new genus of lithistids is named *Paropsites*. Figures are given of the new forms and of their spicular structures.

213. 1883 POČTA, P. Einige Bemerkungen über das Gitterskelet der fossilen Hexactinelliden (*Sitzungsab. der Königl. böhm. Gesells. der Wiss. Prag. Jahrg.* 1882, p. 378).

Gives a detailed description of the spicular structure of this group of Sponges, and of its modifications in different genera.

214. 1884 DUNIKOWSKI, E. Ueber Permo-Carbon. Schwämme von Spitzbergen (*Kongl. Svenska. Vetensk. Akad. Handl.*, Bd. 21, sep. cop., pp. 1—18, Pl. LII).

The Sponges are stated to be of a fibrous character, and the fibres are composed of monactinellid spicules. They are placed in a new genus, *Pemmatites*, and divided into four species and varieties. Their state of preservation is so unfavorable that there is room for doubting whether their true characters have been ascertained.

215. 1884 ZITTEL, K. A. Ueber Astylospongidae und Anomocladina (*Neues Jahrb. f. Min.*, Bd. ii, pp. 75—80, Pls. I, II).

From further study the author sees reason to alter his former views

respecting the skeleton of *Astylospongia*, and now regards it as consisting of simple rodlike spicules branching at both ends. By the interlocking of the branching extremities the nodes are formed. The family *Astylospongiidæ* is removed from the Hexactinellidæ and placed with the Anomocladine family of lithistids. The previous definition of the characters of this family is altered, and the elementary spicules of the skeleton are stated to consist of simple, straight or curved, rod-like spicules with branching extremities. In the family are included *Astylospongia*, *Palæomanon*, *Protachilleum*, *Eospongia*, *Melonella*, *Cylindrophyma*, *Mastusia*, and the existing genus *Vetulina*. The genus *Didymosphæra*, Link, is regarded as equivalent to *Cylindrophyma*, Zitt. *Lecanella*, Zitt., and *Hindia*, Dunc. are placed in the family *Megamorina*.

216. 1884 POČTA, P. Ueber isolirte Kieselspongiennadeln, aus der böhm. Kreideformation. Ueber Spongiennadeln des Bräusauer Hornsteines (*Sitzungsber. der. k. böhm. Gesell. der Wiss.*, pp. 1—14, 243—254, 3 pls).

Numerous detached spicules of tetractinellid, lithistid, and also of hexactinellid Sponges are described and figured. Many are similar to those occurring in the Cretaceous strata of England.

217. 1884 HINDE, G. J. On the Structure and Affinities of the Family of the Receptaculitidæ, including therein the genera *Ischadites*, Murch. (= *Tetragonis*, Eichw.); *Sphærospongia*, Pengelly; *Acanthochonia*, gen. nov., and *Receptaculites*, DeFrance (*Quart. Journ. Geol. Soc.*, vol. xl, pp. 795—849, Pls. XXXVI—XXXVII).

These fossils are regarded as siliceous hexactinellid Sponges in which one ray of the regular spicule is modified to form a rhomboidal or hexagonal plate. The history and geological distribution of the genera are given, as well as a revision of the different species.

218. 1884 HINDE, G. J. On Fossil Calcisponges from the Well-boring at Richmond (*Quart. Journ. Geol. Soc.*, vol. xl, pp. 778—783, Pl. XXXV).

Describes several new species of minute Sponges, in some of which the spicular structure can be distinguished in thin sections. The strata from whence they come are probably of Jurassic age.

219. 1884 HALL, JAMES. Descriptions of the Species of Fossil Reticulate Sponges, constituting the Family Dictyospongiidæ (*Thirty-fifth Annual Report of the New York State Museum*, pp. 465—481, Pls. 18—21).

These bodies are described as fronds consisting of a reticulation of tubular spicules forming rectangular meshes, which alternate in size and strength, owing to the alternation in the size of the bundles of spicules. Three layers are stated to be present. Nothing is stated of the form of the spicules. The

following genera are proposed; their characters are mainly based on the external form of the bodies; *Cyathophycus*, *Dictyophyton*, *Ectenodictya*, *Lyrodictya*, *Thamnodictya*, *Phragmodictya*, *Cleodictya*, *Physospongia*, and *Uphantænia*.

220. 1884 HOERNES, R. Elemente der Palæontologie.

Fossil Sponges are placed under Cœlenterata. The classification and descriptions of Zittel are closely followed, and the figures are likewise nearly all borrowed from the works of the same author.

221. 1884 CARTER, H. J. On the *Spongia coriacea* of Montagu = *Leucosolenia coriacea*, Bowk., together with a new variety of *Leucosolenia lacunosa*, Bowk., elucidating the spicular structure of some of the Fossil Calcispongiæ, followed by illustrations of the pinlike spicules on *Verticillites helvetica*, De Loriol (*Ann. and Mag. Nat. Hist.*, vol. xiv, pp. 17—29, Pl. I).

Describes the stem of *Leucosolenia lacunosa*, var. *Hillieri*, as solid and formed of central triradiates with an outer layer of minute vermiform triradiate spicules, similar to those of many fossil Pharetrones.

222. 1885 POČTA, P. Beiträge zur Kenntniss der Spongien der böhm. Kreideformation. III Abtheil., Tetractinellidæ, Monactinellidæ, Calcispongiæ, Ceratospongiæ, Nachtrag (*Abhandl. der k. böhm. Gesells. der Wissen.*, vii Folge, 1 Band, sep. cop., pp. 1—40, Pl. I).

Numerous forms of detached spicules belonging to the two first-named orders are described; they resemble closely those occurring in strata of the same age in England and Germany. Many new species of calcisponges are described, but in most instances the microscopical structure cannot be recognised. A new genus *Parenia* is also proposed. The author opposes the view of Dunikowski respecting the secondary origin of the fibres in the family Pharetrones. Reference is made to casts of branching cylindrical bodies, supposed to be *Ceratospongia*, but there are no evidences of organic structure in them to support the theory.

223. 1885 SCHLÜTER, C. Ein schon länger bekannte Spongie des rheinischen Devon (*Sitzungsber. der niederrh. Gesells. in Bonn*, p. 151).

Constitutes a new genus *Octacium*, for detached eight-rayed spicules hitherto included under *Astræospongia*.

224. 1885 QUENSTEDT, F. A. Handbuch der Petrefaktenkunde, 3rd Ed.

Sponges are treated in the same desultory manner as in the 'Petrefakten Deutschlands' of the same author; no definite classification is introduced; and they are for the most part ranged in the obsolete genera of Goldfuss and

Schweigger. Fossil calcisponges do not appear to be even named, and *Stromatopora* is still retained in the Sponges.

225. 1885 SOLLAS, W. J. On the Physical Characters of Calcareous and Siliceous Sponge-spicules and other Structures (*Scientific Proc. Royal Dublin Soc.*, n. s., vol. 4, pp. 374—392, Pl. XV).

Describes methods for determining the refractive-index and specific gravity of spicules of siliceous and calcareous sponges; treats also of the optic axis and angles of extinction, and of the effects of etching of calcisponge spicules. States that the Pharetrones must now be relegated to the Calcispongiæ; but *Pharetrospongia* is certainly a siliceous Sponge. Many spicules of calcisponges are shown to be elliptical in transverse section.

226. 1885 SOLLAS, W. J. On an Hexactinellid Sponge from the Gault, and a Lithistid from the Lias of England (*Scientific Proc. Royal Dublin Soc.*, vol. 4, pp. 443—446, Pl. XXI).

Describes as new species *Platychonia Brodiei* and *Craticularia calathus*. Figures are given of their form and structures.

227. 1885 SOLLAS, W. J. On Vetulina stalactites, O. Schmidt, and the Skeleton of the Anomocladina (*Proc. Roy. Ir. Acad.*, S. 2, vol. iv, pp. 486—492, Pls. III, IV).

Shows that the elementary spicules of this recent species consist, as O. Schmidt described them, of central nodes from which a variable number of rays extend, and concludes that the spicules of *Astylospongia* and other fossil *Anomocladina* are of a similar character. The views of Zittel that the elementary spicules of this family are simple rodlike spicules with branching extremities are thus shown to be untenable. Gives a fresh definition of the family *Anomocladina*, similar to that first proposed by Zittel in the 'Studien.'

228. 1885 POČTA, P. Ueber zwei neue Spongien aus der böhmischen Kreideformation (*Sitzungsb. d. k. böhm. Gesell. der. Wiss.* sep. copy, pp. 1—7, Pl. 1).

Describes and figures as two new species *Casearia cretacea* and *Verrucocelia uræformis*.

229. 1885 KATSER, E. *Lodanella mira*, eine unterdevonische Spongie (*Zeitsch. d. deutsch. geol. Gesell.*, pp. 207—211, Pl. XIV).

The form thus named consists of the negative casts of a funnel-shaped body whose walls were penetrated by anastomosing canals. No structure whatever has been preserved, and the character of the organism cannot therefore be determined.

230. 1885 HINDE, G. J. On Beds of Sponge-remains in the Lower and Upper Greensands of the South of England (*Phil. Trans. Roy. Soc.*, Pt. II, pp. 403—453, Pls. 40—45).

Strata of chert and siliceous rock are shown to consist mainly of various forms of detached spicules of siliceous Sponges. These spicules principally belong to tetractinellid and lithistid Sponges, but monactinellid and hexactinellid Sponges are also represented. The spicules are figured and described, and reference is made to the changes produced in their structures by fossilization.

231. 1882—1885 VOSMAER, G. C. J. Porifera (*Bronn's Klassen und Ordnungen des Thier-Reichs*, Lief. 1—11).

The work mainly treats of recent forms. The Porifera, fossil and recent, are divided into two classes: (1) *Porifera calcarea*, and *P. non-calcarea*. In this latter are included (Order 1) Hyalospongiæ (= Hexactinellidæ); (2) Spiculispongiæ (= Lithistidæ, Tetractinellidæ, Myxospongiæ, Monactinellidæ, pars); (3) Cornacuspongiæ (= Monactinellidæ, pars, Ceratospongiæ). Zittel's classification is mainly followed in the subdivisions of the fossil forms.

232. 1885 FEISTMANTEL, KARL. Spongien-Reste aus silurischen Schichten von Böhmen (*Sitzungsb. d. Königl. böhm. Gesell. d. Wiss. in Prag. Jahrg.* 1884, p. 100).

Records the occurrence of detached complete six-rayed hexactinellid spicules, in cherty rock of Lower Silurian (Cambrian?) age in various localities in Bohemia.

## GENERAL CHARACTERS.

Sponges may be defined generally as animals with bodies of very variable form and size, consisting principally of a soft fleshy mass enclosed in a delicate skin. The body is penetrated by a system of canals and minute chambers which communicate with the exterior by larger, and numerous smaller, apertures. With few exceptions they secrete a skeleton, either of horny fibres or of siliceous or calcareous spicules.

Only the skeletal structures of the Sponge are preserved in the fossil state, but the true significance of these can only be properly understood by a consideration of the soft, vital portions of the organism as shown in existing Sponges. There is every reason to believe, from the substantial identity of the skeleton in recent and fossil forms, that the soft structures of the fossil forms were also essentially similar to those of the recent animals.

In all recent Sponges the free outer surface of the Sponge, as well as the interior lacunæ, and the canals leading from the surface to the ciliated chambers, are lined by a delicate membrane, consisting of a single layer of flattened, polygonal, nucleated cells forming an epithelium. This is regarded as proceeding from the ectoderm of the larva, and therefore styled the ectoderm<sup>1</sup> (Schulze). A similar layer of epithelial cells lines the canals leading from the ciliated chambers to the exterior, and this is regarded as of entodermal origin. The ciliated chambers or sacs are lined by cells of sub-cylindrical form, each furnished with a slight projecting collar and a slender flexible cilium or flagellum, also belonging to the entoderm. The surface epithelium is penetrated by numerous minute pores, either disposed singly or grouped together, which open into the lacunar spaces or into canals which convey the water into the interior of the Sponge, and these pores are usually surrounded by contractile fibres, by which they can be closed and opened. It is also penetrated by larger apertures, the vents, or oscules, which are the terminations of the canals conveying the water to the exterior, after it has passed through the ciliated chambers. These apertures may be either scattered over the surface of the Sponge, or grouped round a large central cavity, the cloaca, opening to the exterior.

The greater portion of the body-substance in living Sponges belongs to the mesoderm, and consists of a soft gelatinous, or, in some cases, cartilaginous ground-mass of connective tissue, in which are nuclei, granular particles, contractile fibres, and various other forms of cells, possessing different functions. Some of these cells are amoeboid, others spindly or stellate, whilst others are ova and sperm-sacs.

<sup>1</sup> "On the Structure and Arrangement of the Soft Parts in *Euplectella aspergillum*," 'Trans. Roy. Soc. Edinb.', vol. xxix, p. 669, 1880.



The late discoveries of Mr. C. Stewart and of Dr. von Lendenfeld also clearly show that in many Sponges nerve-cells are present. The skeletal structures of the Sponge are also products of the mesoderm, and the siliceous and calcareous spicules probably all originate in cells, though their character has not yet been definitely ascertained.

The physiological characters of Sponges have not yet been thoroughly worked out. It has long been known that the water containing the food and respiratory supplies entered by the pores, and, after circulating through the incurrent canals and the ciliated chambers, found its way to the exterior by the excurrent canals and the vents or oscules, but it is not yet certain whether the food is ingested by the cells lining the incurrent canals as well as by those of the excurrent canals or merely by these latter. The flagellated cells of the ciliated chambers were formerly believed to ingest the food, but they are now regarded as performing respiratory and excretory functions as well as promoting the circulation of the water through the Sponge.

#### FORM OF FOSSIL SPONGES.

In regard to their external form, fossil Sponges present the same extraordinary variety as living examples of the group. It frequently happens that even when all the structural characters of the Sponge have been obliterated, the form remains in the fossil state, and until recently this feature has been employed to a great extent in the definition of fossil species, though it is now known to be so variable, even in the limits of the same species, as to be of very subordinate value. There is no connection between the external form and the skeletal characters, for we meet with the same variety in all the groups of fossil Sponges, whether lithistids, hexactinellids, or calcisponges, nor can one particular form be said to be more especially abundant than another.

Fossil Sponges are present in the form of cups, vases, or platters, and transitional forms between these. Thus, a simple plate-like Sponge may in the process of growth become fan-shaped, and by the further infolding of the walls, and the anastomosing of their margins where they touch each other, it becomes cup- or vase-shaped, or the reverse process may take place, and a Sponge, which in its early stages may be vasiform with a funnel-shaped cloacal cavity, becomes expanded in the progress of its growth, so that the mature form is that of an expanded platter with a small central funnel. As examples of the platter-shaped forms may be cited species of the lithistid *Verruculina*, and calcisponges of the genera *Elasmotoma* and *Rhaphidonema*, whilst *Ventriculites cribrosus*, Phill., is typically vasiform, and *Ventriculites radiatus*, Mant., is expanded with a central funnel. Other

Sponges are sub-spherical or pyriform, as species of *Aulocopium*, *Melonella*, and *Siphonia*; club-shaped, as species of *Phymatella* and *Rhopalospongia*; cylindrical or sub-cylindrical, as in species of *Scytalia* and *Pachinion*; or dendritic, giving off branches from a main stem, as in *Thamnospongia clavellata*, Ben.; or dichotomously branching with partial anastomosis of the branches, as in *Doryderma dichotomum*, Ben. Again, the branches may be compact, or merely traversed by longitudinal canals, as in the series just named, or they may be hollow tubes as in *Sestrocladia furcatus*, Hinde. Some Sponges are nearly spherical, as *Astylospongia præmorsa*, Goldf., and *Plinthosella squamosa*, Zitt.; and others assume the form of mushrooms, as the lithistid *Seliscotho planus*, Phill., and species of the hexactinellid genus *Cæloptychium*. In other cases the growth of the Sponge is irregular, and the form indefinite, as in species of *Plocoscyphia*.

In compound or colonial Sponges, the simple individuals forming the colony are more frequently cylindrical tubes, which spring from the same base, and form the mass either by subdivision or by budding. These tubes are either independent of each other, save where they start from the parent stock, or they partially coalesce together during their growth, and are only separate near their distal ends. It is difficult to determine in many cases whether the entire mass is to be considered as an individual Sponge, or as a group of individual Sponges growing together in a colony. Thus, for example, in many species of *Peronella* the compound Sponge consists of cylindrical tubes growing parallel to, but separate from, each other, except at the point where their growth commences, and the Sponge is regarded as a colony of simple individuals. On the other hand, in *Elasmocælia faringdonensis*, Mant., the cylindrical tubes are precisely similar in character to those of *Peronella*, and each probably has similar functions, but, instead of being separate, the walls are completely united together and enclosed in a common dermal membrane, and the entire mass is regarded as a simple Sponge, whereas strictly it is as much a colony of individuals as a compound example of *Peronella*.

In many fossil Sponges the body of the Sponge is supported on a cylindrical stem or peduncle of varying length and thickness, and frequently having a minute structure differing considerably from that of the body itself. This feature is more particularly shown in lithistid Sponges, and good examples occur in the genera *Chenendopora* and *Siphonia*. It is not so prominent a feature in fossil hexactinellids, though well marked in *Cæloptychium*. In general, fossil Sponges appear to have possessed flattened basal extensions, or elongated, branching, root-like appendages, for the purpose of anchoring themselves in the soft mud of the sea-bottom, or of attachment to other organisms or hard substances. These anchoring appendages take the form of horizontal or obliquely diverging extensions of the stem of the Sponge, or they may spring directly from the basal portion of the body of the Sponge in those cases in which no stem is developed. Such root-like

appendages are commonly present in fossil lithistids and hexactinellids, but in fossil calcisponges the attachment more generally occurs by means of a basal expansion. As more distinctive anchoring appendages may be mentioned the ropes or bundles of long spicular rods proceeding from the base of the Sponge, and penetrating into the bottom ooze, as in the hexactinellid genus *Hyalostelia* (Pl. VI, figs. 2, 3 d).

Though the majority of fossil Sponges appear to have been furnished with means of attachment, others were undoubtedly free in their mature condition, and seem to have merely rested on the sea-floor without being in any way definitely fixed. This is shown by the entire, evenly rounded, and sometimes concave form of the basal portion of the skeleton. Prof. Ferd. Roemer has noted that this free condition is a well-marked peculiarity in most of the Sponges from Palæozoic strata. It is well shown in *Astylospongia* (Pl. II, fig. 5), and *Aulocopium*; in the different genera of the family *Receptaculitidæ* (Pl. II, figs. 1, 2), in *Amphispongia oblonga*, Salt., (Pl. III, fig. 3) in *Phormosella ovata*, H. (Pl. III, fig. 2), and in *Dictyophyton Danbyi*, M'Coy sp. (Pl. II, fig. 4). It also occurs in some Cretaceous Sponges, as, for example, in the hexactinellid genus *Stauronema*, and in the lithistid, *Plinthosella squamosa*, Zitt.

As a general rule, fossil Sponges with thin walls are hexactinellids, but many forms in which the walls are apparently thick also belong to this same group. In this latter case, however, it will usually be found that the apparent thickness is really due to numerous closely arranged foldings of a simple thin wall. In lithistid Sponges, on the other hand, as already remarked by Zittel, the walls are thicker and of a more compact, firm, and stony character, so that they bear more general resemblance to the cœnenchymal tissue of Corals, than to that of normal Sponges. As regards the compact structures of the skeleton, fossil calcisponges resemble lithistids, but in general they can be readily distinguished from Sponges of this latter group, leaving on one side the different nature of their spicular skeletons, by their smaller dimensions and the continuous reticulation of the fibres on their outer surfaces. These distinguishing features of the outer form and general appearance in the different groups of fossil Sponges are frequently largely masked by their condition of preservation, but they will sometimes afford a clue to the real character of the Sponge, when its spicular structure has been destroyed.

In many fossil calcisponges the exterior or under surface is partially or entirely covered by a smooth, even, or corrugated membrane, resembling in general aspect the epitheca of Corals, whilst the upper surface is furrowed and uneven, and destitute of this dermal layer. A similar structure is occasionally present in lithistid and hexactinellid Sponges.

## SIZE.

There is a great amount of variation in the dimensions of fossil Sponges, though not reaching to the extremes present in living forms. The smallest fossil examples at present known are calcisponges, of which two species have been described, *Blastinia pygmæa*, H., and *Peronella nana*, H., varying from 2·7 mm. to 5·2 mm. in length, and 3·5 mm. in width; or about the size of peas. On the other hand, cylindrical lithistid Sponges, belonging to *Stichophyma tumidum*, H., and *Doryderma Benetti*, H., reach an extreme length of 390 mm. ( $15\frac{1}{2}$  inches), and a thickness of 125 mm. (5 inches). An open cup-shaped lithistid, *Kalpinella rugosa*, H., is 110 mm. ( $4\frac{1}{2}$  inches) in height, and 230 mm. ( $9\frac{1}{4}$  inches) in extension at the summit. Fossil hexactinellids do not attain the same large size as the largest lithistids; an example of *Ventriculites cribrosus*, Phill. sp., is 240 mm. in length by 55 mm. in width at the summit, and an imperfect specimen of *Sporadoscinia capax* is 170 mm. in height by 168 in width at the summit. Fossil calcisponges are, as a rule, smaller than those of other groups, but exceptional examples of *Elasmostoma* and *Pharetrospongia* reach a length and width of 100 to 200 mm. (4 to 8 inches).

## CANAL-STRUCTURES.

The canals in living Sponges form usually a complex system of anastomosing tubes, of varying degrees of fineness, lined by epithelial membrane. In fossil Sponges the canals consist of cylindrical channels bounded by the spicular tissues, in the same manner as those shown in macerated and dried specimens of recent horny and siliceous Sponges. In the fossil, as in the dried recent examples, all the finer canals have disappeared, and only the course of the larger can be made out in the skeleton. Further, in the fossil specimens the canals are not infrequently now infilled with the calcareous or siliceous rocky material in which the Sponge is embedded, and in some cases they are so filled with resistant silica that they appear as a solid network of fibres standing out on the surface of the Sponge. In many fossil Sponges, more particularly in those with a very open spicular skeleton, no distinctive canal-system can be discovered; and these forms are usually described as being without canals, but there can be no doubt that such Sponges in the living state possessed canals, the course of which, owing to the open character of the skeleton, is not shown. In other fossil Sponges, the walls bounding the larger canals consist of a distinct spicular membrane of a finer character than the ordinary skeletal tissues of the body.

In fossil Sponges, as in recent forms, there appears to be two distinct systems

of canals; one, the incurrent system, leading from the surface to the interior of the Sponge, and the other or excurrent passing from the interior and opening out at the surface or into the cloaca. The incurrent canals (Fig. 1, *in.*) are, as a rule, much smaller than the excurrent; they commence at the surface by small circular apertures which are distributed irregularly, and extend into the sponge-wall either

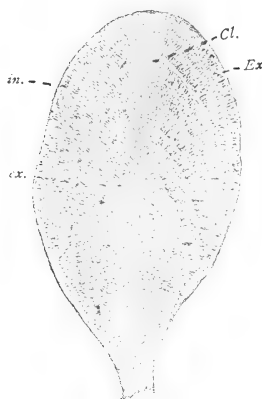


FIG. 1.—*Siphonia tulipa*, Zittel. A vertical median section through the Sponge, showing the cloaca (*cl.*), the fine incurrent canals (*in.*), and the excurrent canals (*ex.*) opening into the cloaca. From the Upper Greensand at Warminster, Wilts. Natural size.

at right angles or obliquely to the surface. The apertures of these incurrent canals have usually been named "pores," but, as<sup>1</sup> Dr. Holl has already remarked, they are not analogous to the pores in living Sponges, which are minute apertures in the soft surface membrane of the Sponge, and could not, therefore, be represented in the skeleton. The apertures in the fossil Sponge rather correspond to the openings of the incurrent canals in the recent forms, and may be either termed incurrent-canal apertures, or, as Sollas names them, ostia. The excurrent canals (*ex.*, Fig. 1) are much more prominent than the incurrent, and less numerous. They open out by circular apertures, either at irregular intervals on the upper surface of the Sponge, or they converge to the infundibuliform or tubular cavity in the centre of the Sponge, which is known as the cloaca or cloacal tube (*cl.*, Fig. 1). Sometimes the excurrent canals terminate at the surface in papilliform projections, with the aperture at the summit. Their apertures are known as oscules or vents, but the former term has sometimes also been employed for the cloaca itself.

<sup>1</sup> "Notes on Fossil Sponges," 'Geol. Mag.,' 1872, vol. ix, p. 346.

In many fossil Sponges the cloaca is altogether absent, or it is merely represented by a slight shallow depression at the summit of the Sponge. Thus, in extended platter or fan-shaped Sponges no cloaca is present, and the excurrent canals usually terminate on the upper or inner surface of the sponge-wall; though occasionally they appear on the under or outer surface, and in some instances even on both surfaces of the wall. In other Sponges of cylindrical or conical form, in which the cloacal cavity is not present, the excurrent canals generally extend longitudinally throughout the length of the Sponge, and the vents open at the rounded or truncate summit. As a rule, the difference in the size of the vents and of the ostia or incurrent-canal apertures, is sufficient to determine their respective characters; but in some Sponges the difference is too slight to enable them to be separately distinguished.

In no instance, so far as I am aware, is the presence of ciliated chambers indicated in the skeleton of any fossil Sponge, owing no doubt to their minute dimensions.

*Canal-system in Fossil Monactinellid and Tetractinellid Sponges.*—So few of these Sponges are preserved in an entire form in the fossil state that very little has been ascertained respecting their canal-structures. In the fossil genera of *Pachastrella*, *Opetionella*, and *Scoliorhaphis*, there are only irregular interspaces between the spicular tissues, and no definite canals; radial canals are present in *Climacospongia*; and in fossil *Cliona* the circulation appears to have been similar to that of the recent species of the genus, and the vents opened at the surface through the circular apertures made in the shell inhabited by the Sponge.

*Canal-system of Fossil Lithistid Sponges.*—In this group Zittel<sup>1</sup> enumerates six different modifications of the water-circulation.

(1) That in which a special canal-system is altogether wanting. This, of course, means that the canal-system must have been disposed in the irregular interspaces of the skeletal mesh, since there are no indications of it in the skeleton itself. Sponges in which this condition occurs have no cloaca, and no special vents; as examples may be mentioned some species of *Platychonia* and *Holodictyon*.

(2) The sponge-wall is penetrated more or less deeply by branching canals of varying size, which open at the surface, the larger being the vents of the excurrent canals, and the smaller the apertures of the incurrent canals. The vents usually open on the upper surface of the wall, and the incurrent-canal apertures on the under surface. The canal-apertures in some instances are equal in size on both surfaces of the walls, and the vents cannot then be distinguished from the incurrent canal-apertures. Sometimes the canals enter the wall obliquely. In certain instances the excurrent canals are nearly horizontal, and have a stellate arrangement round the vent. Sponges with this system are platter- or open cup-shaped,

<sup>1</sup> 'Studien,' ii Abtheil., p. 75.

and without cloaca. Typical examples belong to *Verruculina*, *Chenendopora*, and *Kalpinella*.

(3) In this system a well-marked cylindrical or funnel-shaped cloaca is present. The excurrent canals can be traced from near the outer surface to the cloacal cavity, in which the vents are disposed either in rows or irregularly; the canals are either simple or branched, and nearly horizontal in direction. The incurrent canals begin near the cloacal surface and radiate outwards, opening at the surface of the sponge-wall. The Sponges are usually cylindrical or clavate. This system is present in the genera *Cylindrophyma* and *Phymatella*.

(4) This modification closely approximates to the preceding. It occurs in sub-spherical or cylindrical Sponges with deep and narrow cloacal tubes. The incurrent canals are numerous, fine, and unbranched; they extend either horizontally or obliquely from the outer surface to the interior of the wall. In some instances the excurrent canals open into the cloacal tube as in the preceding modification, and they also appear as open furrows radiating down the sponge-wall from the margins of the cloacal aperture. This modification occurs in *Scytalia* and *Pachinion*.

(5) In this the incurrent system is represented by numerous delicate canals extending from the outer surface of the Sponge in an arched direction towards the centre, whilst the excurrent system consists of relative large canals which extend from the basal portion of the Sponge in a generally vertical direction parallel to its contour, and open into the cloaca. These excurrent canals are frequently shown as open furrows on the outer surface of the Sponge, extending from the margins of the cloaca to the lower portion of the body. In the living condition they were covered over by the soft dermal tissues, as well as by the skeletal dermal layer of spicules, which is now rarely preserved *in situ*. These superficial excurrent canals, now represented as open furrows, would, in the further growth of the Sponge, become enclosed by the skeletal mesh, and then resemble the present internal canals, which have all, in their turn, been formed just beneath the dermal surface of the Sponge.

This canal-system is typically developed in *Siphonia* (fig. 1), *Melonella*, *Aulocopium*, and *Astylospongia*; and it is also present in those lithistid Sponges of conical, cylindrical, or branching form, in which no cloaca is developed, and the vertical excurrent canals extend the entire length of the Sponge, and open at its summit, either grouped in bundles or apart from each other. In the branching Sponges the vertical canals extend the entire length of the branches, and open at their distal ends. In these Sponges the finer incurrent canals are either horizontal or oblique in their course, similar to those in Sponges where a cloaca is present. Examples of this type belong to *Jereica*, *Stichophyma*, *Doryderma*, and *Jerea*.

(6) In this last division the massive wall of the Sponge is divided up into

delicate vertical laminae, with narrow, simple, or branched intervening fissures so as to give the Sponge a radiate appearance like that of a Coral. The canals follow the course of these fissures, thus running radially from the outer surface in a generally horizontal direction to the centre of the Sponge. Their apertures are disposed in the fissures over the lateral surface in vertical rows. The vents are situated on the upper or inner surface of the sponge-wall. In this division are included the Jurassic genera *Cnemidiastrum* and *Corallidium* and the Cretaceous *Seliscotho*.

*Canal-system of Fossil Hexactinellids.*—As the mode of growth in the majority of fossil hexactinellids consists of a thin wall of spicular meshwork, offering a largely extended free surface to the surrounding medium, the canal-system is not of so complex a character as in lithistid Sponges, in which the skeleton is much thicker. In general there is a system of short, blind canals penetrating the thin wall on both sides at right angles to the surface, and extending nearly through it. In addition to these, in some cases a system of pseudo-canals or inter-canals is produced, by various infoldings in the walls themselves, and by the development of a supplementary dermal layer of spicular tissue lining the outer surface of the Sponge and the cloacal cavity, and thus forming a sac-like cavity in which the folds of the wall are contained. The following are some of the modifications of the canal-system in this group.

(1) In which special canals are not present, or are not indicated in the spicular meshwork of the skeleton. In this case the sponge-wall consists of a simple extended layer of spicular mesh, in which only the ordinary quadrate interspaces between the spicules are present. An outer modified spicular dermal layer may be present with regularly disposed apertures, but these are not connected with canals. The genus *Callodictyon* is a typical example.

(2) In which there are special canals extending quite through the sponge-wall. In general appearance the wall of the Sponge differs but little from that of the preceding, but on close examination it is seen that the tubular canals which penetrate quite through it, at right angles to the surface, are not mere ordinary openings in the spicular mesh, but they are definitely bounded by a modified arrangement of the spicular rays of the mesh. A dermal layer is present. This modification is clearly shown in the genus *Aphrocallistes*.

(3) In which the canals terminate blindly in the sponge-wall. In this case the small tubular canals are present on both surfaces of the sponge-wall, and communicate with the exterior by small circular apertures. They reach nearly through to the opposite surface of the wall and terminate blindly. They are usually disposed in alternate rows on the respective surfaces, so that in the interior of the wall the canals are side by side. It seems probable that these blind canals belong to the excurrent system and that the water entering through the smaller apertures of the dermal



layer reached the ciliated chambers, and then passed to the exterior through them. This canal-system is typically seen in the genera *Craticularia*, *Guettardia*, *Coscinopora*, and *Stauronema*.

(4) In which an inter-canal system is developed. In addition to the tubular blind canals in the proper wall of the Sponge, a secondary system of lacunar spaces and anastomosing channels is produced by the infolding and convolutions of the walls. As a well-known example may be mentioned the genus *Ventriculites*. In Sponges of this genus the spicular membrane of the wall is disposed in a series of closely-arranged vertical folds, and the outer surface exhibits vertical ridges and furrows in which are rows of elongated apertures. These apertures are connected with the interspaces between the folds of the wall, as may be seen in a transverse section through the Sponge, and therefore belong to the inter-canal system. The interior surface of the Sponge, next the cloacal cavity, or on the upper surface where no cloaca is present, is usually lined with a dermal membrane with regularly arranged circular apertures, which likewise connect inwardly with the interspaces between the folds of the wall. The genus *Cephalites* has a disposition of the inter-canal system similar to that in *Ventriculites*.

In *Camerospongia* and *Cystispongia* the laminated walls of the Sponge are still further folded, and contained as in a sac by an outer spicular membrane, in which there may be a funnel-shaped cloaca, or merely several wide apertures leading directly into the interior of the sac. In the genus *Plocoscyphia* the folds of the wall are very complex, and they generally anastomose so as to form an intricate system of wide tubes and lacunar spaces which belong to the inter-canal system. The walls themselves usually possess a distinctive perforated dermal layer, and they are penetrated on both sides by blind canals, like the walls of those Sponges in which no folds occur. In the genus *Caloptychium* the folded walls of the Sponge are contained as in a case by a rigid spicular, perforated dermal layer, which freely admits the flow of water into the internal cavity; and on the ridges of the under surface of the Sponge, formed by the folding of the wall, there are rows of oval or elongated apertures, which may be compared to vents.

*Canal-system of Fossil Calcisponges.*—In a single genus, *Protosycon*, there appears to be a similar arrangement of the canals as in Haeckel's family *Sycones*. In this form the walls are penetrated by horizontal tubes or radiate canals which open into the tubular cloaca. In some calcisponges no distinctive canal-system is shown in the disposition of the spicular fibres of the skeleton, and the canals in the living animal must have followed the interspaces between the fibres. Thus in some species of *Peronella*, in which the Sponge is cylindrical, with an axial cloacal tube, no traces of canals appear in the skeleton, and the canals, which most probably in the living Sponge opened into the cloaca, entered through the ordinary interspaces of the skeletal fibres. Also in *Pharetrospongia* and *Pachytilodia*, in which the walls

are frequently of considerable thickness, and the interspaces between the skeletal fibres are comparatively large, no distinctive canals are present. In other calcisponges a system of branching canals extends from the interior of the wall, either to the cloacal cavity or to the general upper surface of the Sponge, terminating in single vents or in small groups of vents. In some forms also open canals radiate from the margins of the cloacal cavity down the sides of the Sponge. Examples of this structure are shown in *Sestrostomella*, *Stellispongia*, and *Lynnorea*. In the genera *Elasmostoma* and *Rhaphidonema*, one surface of the sponge-wall is covered with a minutely perforate dermal layer, whilst the opposite surface has larger scattered vents, which are connected with branching canals. In *Tremacystia* the wall, consisting of but a single layer of spicular fibre, is perforated by circular apertures which lead into hollow chambers, and these latter are connected together by a cribriform axial tube, which opens at the summit of the Sponge and probably represents the cloaca.

#### CHEMICAL CONSTITUTION AND MODE OF PRESERVATION OF FOSSIL SPONGES.

Only those Sponges are definitely known as fossil in which the skeleton was originally either of siliceous or calcareous composition. Sponges with keratose or horny skeletons have not with certainty been shown to exist in the fossil state. The changes which have taken place in the mineral structure of both siliceous and calcareous Sponges during fossilization, have, in many cases, so completely altered their original nature that it requires careful study and considerable experience to determine the groups to which they belong. It is owing to these changes not having been properly understood that so much misconception has arisen respecting the real nature of these organisms, and the supposed radical differences between them and existing forms; and it is therefore a matter of the first importance in the study of fossil Sponges to consider somewhat in detail the changes by which their primary structures have been so largely modified.

1. *Siliceous Sponges; the nature of the Silica, and the changes in it during fossilization.*—The silica forming the skeletal spicules and spicular mesh of recent Sponges, is in the amorphous or colloid condition, beautifully clear, like a perfect glass, and quite negative in polarized light, between crossed Nicols. It is also soluble in heated caustic potash. It is very rare to find the silica of fossil spicules retaining the same brilliant glassy appearance and structure as in the recent forms; and, so far as I am aware, this perfect condition of preservation is only found in detached spicules and fragments of spicular mesh, which have been preserved in a matrix of fossil diatomaceous or radiolarian earth of Tertiary age. Spicules in this condi-

tion are present in a diatomaceous rock of the pre-Miocene age from Oamaru, New Zealand, and in marls from St. Peter, Hungary.

In fossil siliceous Sponges the silica may be either (*a*) amorphous or in the colloid state; (*b*) chalcedonic or cryptocrystalline, or (*c*) crystalline. It may also be replaced by glauconite, or other mineral silicate; or dissolved so as to leave empty negative casts of the spicular skeleton in moulds of limestone, chalk, or silica; or the moulds may be infilled and the silica replaced by crystalline calcite, iron-pyrites, or iron peroxide. The siliceous skeleton may, further, be entirely dissolved without leaving any mould or trace of its presence, whilst the form of the Sponge is retained, and the canals infilled with a solid mass of silica. The Sponges may still consist of silica, but the minute structure of the skeleton may be partially or entirely obliterated, and the silica re-deposited as chalcedony. In this state the Sponges in the Chalk are frequently enclosed in an outer casing of solid flint.

(*a*) The silica amorphous. In this case the silica of the Sponge skeleton is in a colloid condition, like that of recent Sponges, and it presents the same reaction to heated caustic potash, and it is likewise negative to polarized light, but it has lost the brilliant glassy aspect present in the siliceous skeleton of recent Sponges. The skeleton of Sponges in this condition has a porcellaneous, milky-white appearance by reflected light; and in transmitted light, when mounted in Canada balsam, it is nearly transparent, and the silica appears to be in the form of minute granular particles with a pinkish reflection, and not infrequently of minute spherules or discs. If mounted in glycerine the spicules become so transparent that nothing more than faint outlines of their forms can be seen. As a rule the surface of the spicules, in which the silica retains the original amorphous condition, is smooth and even, and the axial canals are usually wider and therefore more distinct than in recent forms. These axial canals appear in many instances to be now filled with chalcedonic or crystalline silica, and they frequently remain after the more soluble silica of the spicular walls has been dissolved away. Sponges in which the silica remains amorphous are comparatively rare, and in this country I have only seen examples from the Upper Greensand of Wiltshire; but they are common in glauconitic marls of Senonian age in North Germany. Detached spicules in this condition are present in considerable numbers in the interior of masses of chert from the Upper Greensand of Wilts, and in nodules in the so-called malm or firestone rock, of the same geological horizon, at Merstham, Surrey.

(*b*) The silica is cryptocrystalline or (*c*) crystalline. The spicular skeleton, in which the silica is in either of these states, has by reflected light either a pure snowy white tint, or a dull glassy appearance, not unlike that of ground glass. When mounted in Canada balsam, and viewed by transmitted light, the spicules become so transparent that but little more than their contours can be distinguished, but in glycerine their forms stand out very distinctly. In polarized light they

exhibit between crossed Nicols the same shades of colour as chalcedony and quartz, and in many instances in the same spicule there is a gradual passage from the chalcedonic to the crystalline state of the silica. The outer surface of the spicular skeleton in this condition of the silica is rarely smooth, but generally much eroded, and apparently covered over with minute pitted depressions, which give the skeleton a very ragged appearance under the microscope, and the delicate extensions of the spicular rays appear as if largely worn away by erosion. The axial canals also of the spicules can rarely be detected, probably owing to the fact of their having been infilled with silica of the same optical character as the wall of the spicule, and therefore indistinguishable from it. In the majority of siliceous Sponges in which the skeleton has been preserved the silica is now in the condition of chalcedony. In some, however, the change has reached a further stage, and it is altogether crystalline. The experiments of Mr. Hannay<sup>1</sup> on the siliceous fossilization of the Sponge-spicules from the Lower-Carboniferous Rocks of Scotland show that the change from the amorphous silica of recent Sponges to the cryptocrystalline and crystalline silica of the fossil forms is mainly owing to the loss of chemically-combined water, which causes crystallization to set in.

The alteration in the spicular skeleton of the Sponges just referred to is mainly limited to the condition of the silica of which it is composed, and the detailed form of the skeletal mesh and spicules is retained as in existing Sponges; but in many fossil Sponges, notably in those from the Upper Chalk, the skeleton is still of silica, but the skeletal tissues have lost their distinctive form, and the place of the regular spicular meshwork is taken by shapeless fibrous masses of chalcedonic or crystalline silica, which present an appearance as if the original silica of the skeleton had been fused. This alteration is well exemplified in the Sponges from the Upper Chalk of Flamborough, Yorkshire, which, when freed by acid from the chalky matrix, retain for the most part their complete outer form and the fibrous character of the skeleton, but the delicate spicules of which the fibres were originally composed have altogether disappeared, and the fibres are now of shapeless granular particles of silica.

In other cases, as in many of the Sponges from the Upper Chalk of Wilts and elsewhere which have been enclosed in flint, the spicular structure of the outer surface of the Sponge is occasionally still preserved, and consists of crystalline silica of a snowy-white tint, but the structure of the interior is usually changed to a mass of botryoidal or porous chalcedonic silica, in which even the course of the canals has been obliterated. These masses form, as it were, cores within the flints, and are frequently entirely free from the outer casing of flint. Not infrequently between the Sponge and the flint there is a very fine, white, siliceous powder, oftentimes containing detached spicules.

<sup>1</sup> 'Mem. Lit. and Phil. Soc. Manchester,' vol. vi, S. 3, p. 234.

*Siliceous Skeleton dissolved, leaving empty casts.*—The spicular skeleton of many fossil Sponges, after being enclosed in the rock, has been dissolved, leaving hollow impressions of its minute structure in the matrix. The outer form in these Sponges is usually retained by the matrix, which may be either of chalcedonic or crystalline silica, limestone, or chalk. The impressions of the minute spicular structures are usually most distinct when the matrix is of silica, which now forms a solid mass, in which the minute hollow moulds of the skeleton are contained; but even when the matrix is of such a soft material as the Upper Chalk of the South of England, the hollow casts of the spicular skeleton are retained very perfectly, and even such minute structural details as the hollow lantern-nodes of the hexactinellid spicules are clearly shown. Not only entire Sponges occur as empty casts, but even the moulds of detached spicules are also present in the bands of chert and siliceous rock of the Upper Greensand, and frequently to such an extent that the rock is porous and light on account of the numerous minute cavities in it formed by the dissolution of the spicules. In some of these minute fusiform hollows there is an axial filiform siliceous rod, which is the solid cast of the spicular canal, remaining after the walls of the spicule itself have been dissolved away.

Another modification of the process by which the cast of the skeletal structures is retained after the solution of the skeleton itself, is shown in some hexactinellid Sponges from the Upper Greensand, in which the spicular mesh is invested with a delicate pellicle of silica, and then subsequently dissolved, leaving, as it were, an outer shell of its form. A similar alteration has also been recorded by Manzoni<sup>1</sup> in hexactinellid Sponges from the Miocene strata of Bologna, but in these the spicular mesh is in part retained after its investment by the siliceous pellicle.

Examples of the removal, by solution, of the spicular skeleton of siliceous Sponges occur in almost every geological horizon in which Sponges are present. Thus in the Silurian genera *Astylospongia* and *Hindia* the skeleton in many of the specimens forms negative casts in a siliceous matrix; in many of the hexactinellid Sponges from the Upper Chalk of the South of England the hollow moulds of the skeleton are preserved in the soft chalky matrix, and a similar dissolution of the skeleton has also taken place in the siliceous Tertiary Sponges of Bologna.

These undoubted instances of the solution and removal of the silica of Sponge skeletons completely negative the idea, held to within a comparatively recent date, that silica is sufficiently stable to resist the ordinary influences of fossilization. It may be accepted as proved that silica in the colloid state, in which it occurs in the skeleton of recent siliceous Sponges, and also in the original condition of fossil Sponges, is extremely liable to chemical changes, and that it is only when in the condition of chalcedony or crystalline that it can be regarded as stable. The changes in the siliceous skeletons of fossil Sponges, mentioned above, show the

<sup>1</sup> 'Spugne silicee del Miocene medio,' p. 17, pl. 3, figs. 15, 16, 1882.

tendency of the silica to pass from the unstable colloid to the stable chalcedonic and crystalline condition. Under favorable conditions this chemical change has taken place without destroying the form of the spicular skeleton, but in other circumstances the colloid silica of the skeleton has been wholly dissolved away and redeposited, usually in the chalcedonic condition, so as to form solid beds of chert and bands of nodular flints. Some recent experiments of M. Thoulet<sup>1</sup> on existing siliceous Sponges show that the silica is readily susceptible to the solvent influences of the chemical ingredients of salt water, and fossil Sponges have been exposed to similar influences, during the interval of fossilization, from the action of water, charged with chemical substances, percolating through the rocks.

*Siliceous Skeleton replaced by Calcite and Glauconite.*—The form of the Sponge is usually retained in such cases, but instead of the original silica the skeleton now consists of transparent crystalline calcite. As a rule, the Sponges in which this replacement occurs are embedded in a calcareous matrix, and by the action of dilute acid both the matrix and the replaced skeleton are equally dissolved. The replacement does not seem to have been produced by the molecular substitution of the calcite for the silica, but it is probable that the calcite has been deposited from solution into the hollow moulds left by the removal of the original silica. Where the spicular mesh is of an open character, or in the case of large spicules, the original form can be recognised in the replaced structures; but when the spicular mesh is minute and closely arranged, as in rhizomorine lithistids, the calcitic replacement is indefinite and confused, and the distinctive form of the original spicules can no longer be made out. It is thus very difficult to determine the original character of Sponges in this condition. On the other hand, in cases where the calcite has infilled the moulds formed in a matrix of chalcedonic silica, the replaced skeleton presents all the details of the original siliceous skeleton, with such even and clearly defined outlines that it has been mistaken for the original substance of the skeleton, and the Sponge has been described as calcareous. Typical examples of this replacement are shown in specimens of *Astylospongia* from the Silurian strata of Gothland and of *Hindia* from nearly the same horizon in New Brunswick.

This replacement of the siliceous skeleton by crystalline calcite oftentimes takes place in the Sponges of definite horizons in particular localities, whilst at other horizons but little removed the Sponges retain their siliceous structures. Thus, for example, in certain Sponge-beds in the Grey or Lower Chalk near Dover and Folkestone the siliceous structure of the Sponges has been entirely replaced by calcite, whilst the Sponges in the underlying chloritic marls of the same locality and in the Isle of Wight retain the silica. Similar instances are

<sup>1</sup> 'Bulletin de la Soc. minéralogique de France,' T. vii, 1884, p. 147.

recorded by Zittel<sup>1</sup> in the Sponge-beds of the Upper Jura of Switzerland, Wurtemberg, Bavaria, and Poland. In certain localities the entire siliceous skeleton is replaced by calcite, whilst in others the original silica remains, though in the condition of chalcedony. On the other hand, many instances occur in which the calcitic replacement is only partial, even in the same Sponge, and by treatment with acid the calcareous portions are dissolved, whilst fragmentary portions of the siliceous structure remain behind.

The replacement of silica by glauconite is of much less frequent occurrence, but the change has taken place in detached spicules in the Sponge-beds of the Upper Greensand. The glauconite in these specimens appears first to have infilled the axial canal of the spicule, and afterwards to have been deposited gradually, in proportion as the silica of the wall of the spicule has been removed. In other instances the siliceous spicules are replaced by a mineral of a greenish-white tint, apparently allied to glauconite, and nearly entirely transparent when viewed under the microscope in Canada balsam. This replacement is also frequently accompanied by a very peculiar distortion and contraction of the spicules. It occurs in spicules preserved in cavities of Upper-Greensand chert at Ventnor and at Warminster in Wiltshire.

*Siliceous Skeleton replaced by Peroxide of Iron and Iron-pyrites.*—This latter mineral but seldom takes the place of the silica, but the former is of frequent occurrence; and Sponges thus replaced are found in strata from the Silurian upwards, and they are more particularly abundant in the Upper Chalk of the South of England. The peroxide occurs as a rusty, reddish brown, often powdery and incoherent, material. As a general rule the finer structures of the skeleton are not preserved in this material, and they are usually so confused as to be unrecognisable. Rarely, however, as in the case of some of the *Ventriculites* from the Upper Chalk, so carefully worked out by Toulmin Smith, the peroxide is sufficiently firm to allow of the chalky matrix being removed, and the skeletal structure stands out by itself, but it is nevertheless very delicate and perishable. It is somewhat unfortunate that the majority of the siliceous Sponges in the Upper Chalk of the South of England, in which the matrix is the Chalk itself, should have had their skeletons replaced by this incoherent peroxide, since, though their entire forms are retained, and their canal-systems can be made out, the minute characters of their spicular tissues cannot be determined with precision. Not infrequently also the peroxide has replaced the silica in Sponges enveloped in a matrix of solid flint; and the replacement is particularly well shown in specimens of *Ventriculites* and *Plocoscyphia*, whose delicate convolute or labyrinthine walls appear in section on the surface of fractured flint like narrow reddish bands. In some cases these bands show the minute spicular structure, but more frequently it is altogether indistinct and unrecognisable.

<sup>1</sup> 'Studien über fossile Spongien,' i Abth., p. 13, 1877.

In the calcisponges from the Lower Greensand of Faringdon, Berkshire, the fibres are of a greyish tint, and the crystallization has largely obliterated the spicular structure, and in many instances the fibres are invested with an outer coating of calcite crystals. In the Jurassic calcisponges the outer form of the Sponge and the fibres are well preserved, but their minute spicular components have been, to a large extent, destroyed by the secondary crystallization of the calcite, and only occasionally are the larger spicules faintly shown.

It is worthy of notice that, in striking contrast to many siliceous Sponges, in which the skeleton has been preserved in a negative form, as hollow moulds in an enclosing matrix, no undoubted calcisponge has, to my knowledge, been met with in this condition, but in all cases the fibres are present, either as calcite, or, more rarely, replaced by crystalline silica.

*Calcisponges replaced by Silica.*—This replacement is of infrequent occurrence, and it usually takes place in strata in which Corals and other calcareous organisms as well as the Sponges have become siliceous. Calcisponges thus silicified can be obtained quite free from matrix by treatment with acid; their fibres are then of a snowy-white tint, with rough and uneven surfaces, and all traces of the spicular structure have disappeared.

An exceptional mode of preservation is shown in some examples of *Pharetrospongia* from the so-called Cambridge Greensand and from the Upper Chalk of Kent. The Sponges are usually calcareous throughout, but in some instances a partial replacement of the fibres by silica has taken place. When treated with acid the interior portion of the fibres, being calcareous, is dissolved, but a thin exterior pellicle of silica remains, in which the form of the minute acerate spicules can be seen. In the Upper Chalk examples, those which are embedded in the chalky matrix have their fibres entirely calcareous, and they are completely dissolved in acid, whilst in the specimens embedded in flint the outer layer of the fibres is replaced so as to form a thin pellicle of silica, the same as in the Cambridge Greensand specimens. This different mineral condition of the fibres, according as they are enclosed in chalk or flint, may be observed not infrequently in the same specimen, part of which is in the flint, and has the silicified surface-pellicle enveloping the fibre, whilst another portion is in the chalk, and the fibres are throughout calcareous. There can be no doubt that the thin surface-film of silica on the fibres of the flint-enclosed examples of *Pharetrospongia* is owing to the replacement of the original calcite by the silica, such as usually takes place in calcareous organisms enclosed in flints. It has been contended that this genus was originally siliceous, and that the calcareous fibres result from the replacement of the original silica by calcite. That, however, the forms are really calcisponges is further shown by the fact that no other undoubted siliceous Sponge in the Upper Chalk presents the same mineral structure and appearance as these examples of *Pharetrospongia*.



*Modifications in Fossil Sponges resulting from their Spicular Structures.*—Hitherto we have considered the changes produced in fossil Sponges by the chemical alteration of their skeletal constituents, but there are other modifications arising from the way in which their skeletal elements are built up, which have an important bearing on the preservation of the Sponge in the fossil state. Sponges in which the skeletal elements are free from each other, and merely held in position by the soft, fleshy structures of the living organism, cannot, except under very favorable circumstances, be preserved entire in the fossil state, but their skeletal spicules, on the death of the animal, and the decay of the soft tissues, become detached and indiscriminately mingled together in the ooze of the sea-bottom. On the other hand, Sponges in which the skeletal spicules are closely and intimately connected, or organically united together, retain their entire forms, other conditions being favorable, in the fossil state.

Thus the component spicules in monactinellid and tetractinellid Sponges are either only loosely embedded in the soft tissues, or they form anastomosing fibres enclosed in perishable spongin, and as a result entire Sponges belonging to these groups are very rare in the fossil state. As exceptional examples may be mentioned the Carboniferous genus *Haplition*, Young, and from the Cretaceous strata of Germany *Opetionella*, Zitt., and *Scoliorhaphis*, Zitt., whilst some forms of *Ophiraphidites*, and *Pachastrella* occur in the Upper Chalk in this country. In these cases the free spicules are very thickly disposed amongst each other in the body of the Sponge, and the Sponges appear to have been undisturbed whilst they were gradually covered with sediment. In some instances the spicules have been subsequently cemented together by a secondary deposition of silica. In contrast to the rare occurrence of entire Sponges of these groups as fossil, is the abundance of their detached spicules, which, intermingled together, form extensive beds, like those described by Dunikowski<sup>1</sup> from the Lower Lias of Schafberg in the Tyrol, by the writer<sup>2</sup> in the Lower and Upper Greensands in this country, and by Rutot<sup>3</sup> in the Eocene of Belgium. They are also similarly abundant in the Upper Chalk. These detached spicules evidently belong to various genera and species of Sponges, but their entire forms have been wholly destroyed.

In lithistid Sponges, in which the component spicules are more or less intimately united together by the interlacing of their branching extremities, the entire form of the Sponge is usually preserved, though in those belonging to the Megamorina family, in which the union of the spicules is of a simpler character, the Sponges have, to a great extent, been disintegrated, and their component spicules occur detached in great numbers in the Lower and Upper Greensands and in the

<sup>1</sup> 'Denkschr. der Kais. Akad. der Wiss. Wien,' 1882.

<sup>2</sup> 'Phil. Trans.,' Pt. ii, 1885.

<sup>3</sup> 'Ann. de la Soc. Malacol. de Belgique,' Tome ix, 1874.

Chalk. The manner in which these detached spicules are dispersed in the matrix, and their perfect forms, show that this disintegration took place shortly after the death of the Sponge, and before it was covered with sediment, and also that they have not been transported far from the locality in which the Sponges existed. The dispersion of the spicules, when they are not united together into a connected skeleton, is very strikingly shown in the case of those forming the dermal layer of lithistid Sponges, which, unlike those of the body of the Sponge, are free and merely held in position by the penetration of their pin-like shafts into the Sponge. Though there is every reason to suppose that fossil lithistids, like recent ones, were uniformly provided with a dermal layer of differentiated spicules, this is very rarely now retained, but the detached spicules themselves are not infrequently met with dispersed in the matrix.

In the dictyonine group of fossil hexactinellid Sponges, the spicules are completely amalgamated together, and consequently these Sponges retain their entire form even though their walls are frequently of a thin and delicate character. In the lyssakine group, on the other hand, in which the spicules are free from each other, examples of entire Sponges are very rare, but the detached spicules are very abundant in the Lower Carboniferous of Ayrshire and Yorkshire, and also in the Upper Chalk.

Fossil calcisponges as a rule retain their entire forms, and detached spicules of these Sponges are rarely met with. This preservation of the entire form is the more surprising since the component spicules of their skeletal fibres are not organically attached together, and their habitat in shallower water would have exposed them to more disturbed conditions. The spicules in these fibres appear, however, to have been very closely and intimately arranged, and to this may be due the fact that they have not been disintegrated. On the theory of Dunikowski<sup>1</sup> that the fibres of fossil Pharetrones are not original, but produced by fossilization, it is difficult to understand how they could have retained their entire forms, since in all other cases, as we have seen, the effects of fossilization are rather to break up and disintegrate the spicular structures than to consolidate them.

#### SKELETAL STRUCTURES OF FOSSIL SPONGES.

The skeleton of all known fossil Sponges is built up of small<sup>2</sup> mineral particles, usually of microscopic dimensions, and of very varying forms, which are combined

<sup>1</sup> 'Die Pharetronen: Palaeontographica,' Bd. xxix, p. 283, 1883.

<sup>2</sup> Sponges with skeletons of horny fibres have not yet been definitely shown to exist as fossil. Though various forms have by some authors been referred to horny Sponges, there is no satisfactory evidence that they belong to this group. The *Dysidea antiqua* of Carter, 'Annals and Mag. Nat. Hist.,' 1878, vol. i, p. 139, described as a horny Sponge, is a siliceous monactinellid, which had been previously named by Young and Young, *Haplition Armstrongi*, 'Annals, &c.,' 1877, vol. xx, p. 428.

together in different ways, so as either to form a continuous framework or loose open fibres, which serve as a support to the soft fleshy portions of the Sponge. These mineral particles are termed spicules, a word used in a general sense to indicate the individual element or particle of the skeleton, whatever may be its form. The spicules of fossil Sponges, like those of recent ones, are composed either of silica or of carbonate of lime. In all essential features they resemble the spicules of existing Sponges, and it may be assumed that like these latter they have been formed in cells in the mesoderm of the Sponge. Spicules consist of an outer wall of concentric layers, enclosing in most, if not in all cases, a delicate longitudinal axial canal, which extends either partially or entirely the length of the spicule, and into each of its main arms or rays. This axial canal is usually much wider in fossil spicules than in recent forms; in the living condition the canal appears to have been filled with protoplasm, but in the fossil state it is usually occupied by a mineral substance of the same general character as the spicular wall. If the infilling material has the same optical characters as the wall of the spicule, the canal can no longer be distinguished, and the spicule appears solid throughout; but not unfrequently the infilling substance of the canal is more resistant than the spicular wall, and remains even when this latter has been dissolved away. Between each of the concentric layers of the spicular wall there appears to have been originally a thin film of organic substance. The structural layers are but rarely seen in fossil spicules; they can, however, be occasionally distinguished in the rod-like spicules of *Hyalostelia* (Pl. VI, figs. 2 a, 2 c, 3 f).

Two different kinds of spicules are usually recognised in recent Sponges, skeletal-spicules and flesh-spicules, and both kinds are present in the fossil forms, though the latter are of very subordinate importance in the fossil state, owing to their rare occurrence. The skeletal-spicules form the main body of the Sponge and are usually of much larger dimensions than the flesh-spicules. These latter, on the other hand, exhibit a much greater variety of form than the skeletal-spicules; they are not attached together, but merely held in position by the soft tissue of the Sponge, and consequently are not often found in their natural position in fossil Sponges.

The two chief considerations in the study of fossil Sponges are, first, the character of the individual spicules, and next, the mode in which they are combined to form the skeleton. The skeletal-spicules of fossil Sponges have been arranged in groups based on the number and disposition of their axes or rays. Taking first those of siliceous Sponges, the following typical divisions may be enumerated:

1. Monactinellid spicules, or those in which a single axis is present.
2. Tetractinellid spicules, in which there are four rays or axes, which radiate from a common centre in the same direction as the axes of a regular, three-sided pyramid.

3. Lithistid spicules, with four or more rays proceeding from a common centre, or irregularly branching forms.

4. Hexactinellid spicules, with six rays, forming three axes which cross each other at right angles.

5. Octactinellid spicules, with eight rays, six of which are in one plane and the other two form an axis at right angles to the plane.

6. Heteractinellid or polyaxile spicules, with a variable number of rays extending from a common centre.

Various modifications of the typical forms of these different groups are of frequent occurrence. These may arise either by an increase in the number of rays by furcation, or by a suppression of one or more of them. Thus, in tetractinellid spicules subdivision takes place oftentimes in one or more of the principal rays, and the same thing rarely also occurs in hexactinellid spicules; in these, however, suppression of one or more of the normal six rays frequently happens. Again, the spicular rays may become modified so as to form an entire or lobate disc, as in the dermal spicules of some lithistid Sponges.

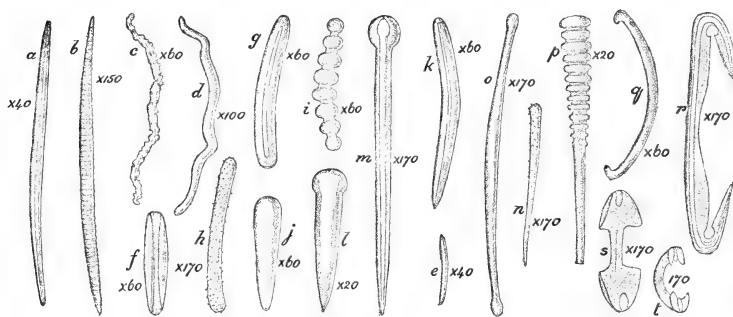


FIG. 2.—Different forms of fossil siliceous monactinellid spicules from Upper Greensand, Chalk, and Tertiary strata. (a) Curved, fusiform, acerate spicule, showing the axial canal open at both ends. (b) Aerate spicule with minute constrictions. (c) Vermiculate nodose acerate from *Scliorhaphis cerebriformis*, Zitt. (d) Vermiculate acerate, smooth. (e) Aerate, acutely pointed. (f) Aerate, probably immature, having the axial canal open throughout. (g) Simple curved cylinder, with axial canal completely enclosed. (h) Cylinder, microspined. (i) Moniliform cylinder, *Monilites Haldonensis*, Carter. (j) Conical spicule. (k) Smooth, curved, acuate spicule. (l) Pin-shaped or spinulate. (m) Spinulate, showing the axial canal. (n) Acuate spicule, microspined. (o) Tibiella, fusiform, with inflated extremities. (p) Moniliform acuate. (q) Bihamate, *Esperites Haldonensis*, Carter. (r) Bihamate or clasp-hook (flesh-spicule). (s) Bispatulate (flesh-spicule). (t) Equianchorate (flesh-spicule).

1. MONACTINELLID SPICULES.—The typical character of the spicules of this group is a simple unbranched axial canal, which generally extends throughout the length

of the spicule and is either open or enclosed by the spicular wall at one or both ends. In the case of many acerate spicules, the canal opens to the exterior at both ends of the spicule (Fig. 2, *a*); in cylindrical spicules it is usually enclosed at both ends by the spicular wall (Fig. 2, *g*), whilst in acuate and spinulate spicules the canal is enclosed at the truncate or inflated head and opens at the apex of the spicule (Fig. 2, *m*). In some forms, which are regarded by Zittel as immature spicules, the canal remains open throughout its length (Fig. 2, *f*). In moniliform spicules like those shown in Fig. 2, *i*, *p*, the canal does not follow the inflations of the spicule, but continues of an even width throughout.

There is very great variation in the form and size of monactinellid spicules; some of the commoner types are represented in the accompanying Fig. 2. The most abundant form is the acerate, generally thickest in the central portion and gradually tapering to the ends (Fig. 2, *a*, *b*). It may be either straight, curved, or vermiculate (Fig. 2, *c*, *d*), either pointed or obtusely blunted; smooth or partially or entirely microspined. Numerous gradations exist between the acerate and the cylindrical forms, which likewise may be straight or curved (Fig. 2, *g*), smooth or more or less spined (Fig. 2, *h*). In acuate spicules the head is truncate or evenly rounded (Fig. 2, *k*, *n*), and the spicule gradually tapers to a pointed extremity, whilst when it tapers abruptly the spicule is conical (Fig. 2, *j*). From these there is a gradual transition to the spinulate or pin-shaped spicules (Fig. 2, *l*, *m*), in which the head of the spicule is variously enlarged and may be either sub-spherical or conical in form. In another form, which has been named tibiella, the spicule is cylindrical or fusiform with inflated ends (Fig. 2, *o*). In some acuate and cylindrical forms the spicule is moniliform and consists of a series of inflated rings with intervening furrows (Fig. 2, *i*, *p*).

There is a still greater range of variation in the form of the minute flesh-spicules associated with the monactinellid skeletal-spicules; some are simply bihamate (Fig. 2, *q*), in others the ends are sharply incurved like those of a clasp-hook (Fig. 2, *r*), and there is a trenchant inner edge; in a third form both ends of the spicule are expanded so that it may be termed bi-spatulate (Fig. 2, *s*), whilst in the very common "anchor" flesh-spicules there are from two to three in-curved grapnel-like hooks at both ends of the spicule, which may be either equal (Fig. 2, *t*) or unequal in size.

2. TETRACTINELLID SPICULES.—The typical spicule of this group has four equal, straight, pointed rays extending from a common centre, so as to form the four axes of a regular three-sided pyramid, the angle between each of the rays thus being  $120^{\circ}$ . A longitudinal canal is present in each ray, extending from the centre to the termination of the ray (Fig. 3, *a*). The modifications of this ground-form are exceedingly numerous. Thus the rays of the spicule may be unequal in length, and one or all of them may be furcate, as in some of the spicules of

*Pachastrella primæva* (Fig. 3, *l*). Again, one of the rays may be reduced to a slight knob, or may not be developed at all, and the spicule becomes tripodal in form (Fig. 3, *b*), and can then scarcely be distinguished from the three-rayed spicules of calcisponges, more particularly when the tripodal elevation is reduced, so that the three rays are nearly in a horizontal plane. An important differentiation is shown in the so-termed trifold or zone-spicules, in which one of the rays is very much elongated and enlarged in proportion to the other three. This elongate ray is known as the shaft of the spicule, it is straight or slightly curved, and usually

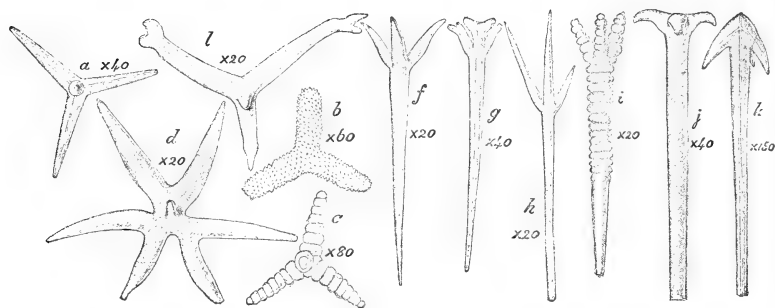


FIG. 3.—Various forms of fossil siliceous tetractinellid spicules from Upper Greensand, Chalk, and Tertiary strata. (a) Regular tetractinellid or four-rayed spicule, *Pachastrella Haldonensis*, Carter. (b) Microspined spicule in which only three rays are developed. (c) Regular four-rayed spicule, moniliform, *Pachastrella quadriradiata*, Carter. (d) Compound trifold spicule, the shaft abbreviated, and the head-rays furcate and extended horizontally. (e) Four-rayed spicule of *Pachastrella primæva*, Zitt., in which two rays are incipiently furcate. (f) Simple trifold or zone-spicule of *Geodites*, sp. (g) Compound trifold or zone-spicule of *Geodites planus*, in which the head-rays are furcate. (h) Simple trifold or zone-spicule of *Geodites*, sp. (i) Simple trifold or zone-spicule, moniliform, *Geodites Wrightii*. (j) Trifold or zone-spicule of *Stelletta inclusa*, Hinde, in which the head-rays are recurved. (k) Trifold spicule in which the head-rays are sharply recurved so as to become anchor-shaped.

tapers to an acute point (Fig. 3, *f*). At the head or distal end of the shaft the three other rays project at various angles. These head-rays vary very much in different spicules. They may be straight or curved, conical, acutely pointed, or club-shaped. In many cases, one or more of these rays divide and become furcate (Fig. 3, *g*), and the canal similarly divides, and an arm extends into each ray. The head-rays diverge from the summit of the shaft either in a forward direction (Fig. 3, *h*), obliquely, horizontally, or they are more or less recurved (Fig. 3, *j*, *k*). Both rays and shaft are

usually smooth, but in some instances they are moniliform as in *Geodites Wrightii*, Hinde (Fig. 3, *i*). These trifid spicules are frequently radiately disposed, so that the head-rays are extended near the outer surface of the Sponge, and hence they have been termed zone-spicules. They are abundant in the existing *Geodia*, Lam., and allied genera, and in the fossil *Geodites*, Carter.

In another form, the spicule is modified in a reverse way to that of the trifid spicules just described, for the ray corresponding to the elongated shaft is reduced to a short blunt process, whilst the head-rays are greatly developed. They are usually furcate, and the rays extend in a generally horizontal direction, forming a right angle with the diminutive shaft (Fig. 3, *d*). These spicules, equally with those in which the shaft is elongated, are disposed at or near the outer surface of the Sponge. They have been referred to the genus *Stelletites*, Carter.

In some of the detached spicules of this group, from Carboniferous strata, only two head-rays have been developed, as in *Geodites deformis* (Pl. V, figs. 4 *d, g*), and similar spicules also occur in the Upper Greensand.

3. LITHISTID SPICULES.—There is such great diversity of form in the spicules of lithistid Sponges that no single example can be quoted as typical of the group as a whole. The skeletal-spicules forming the body of the Sponge exhibit the greatest amount of variation, whilst in many instances the spicules of the dermal layer are extremely regular in form, and present a striking contrast to the skeletal-spicules even of the same Sponge. In what is regarded as the highest developed group of lithistids, the skeletal-spicules consist of four rays, disposed in the same manner as those of tetractinellid spicules, and with an axial canal in each ray; whilst in other divisions the skeletal-spicules give off irregularly secondary rays from a main stem, in which there is a single unbranched canal. But it frequently happens that the dermal spicules of Sponges with this peculiar form of skeletal-spicule are distinctly tetractinellid in type, thus indicating a certain amount of relationship between these divisions. Professor v. Zittel has divided lithistid Sponges into the four families of the *Rhizomorina*, *Megamorina*, *Anomocladina*, and *Tetracladina*, according to the respective characters of their skeletal-spicules.

(a) *Rhizomorina*.—In this family of lithistids the skeletal-spicules usually consist of a slender, curved main axis, from which minute, twig-like branches and spinous processes are given off irregularly. The extremities of the branches, where they come in contact with adjoining spicules, are furnished with minute, flattened facets. A simple axial canal can sometimes be seen extending either partially or throughout the length of the main axis (Fig. 4, *b*), but there are no diverticles from it into the branches. Typical spicules of this character are present in *Seliscotho* *Mantelli*, Goldfuss sp. (Fig. 4, *a, b*). In another form there is a short, relatively stout, main axis, not infrequently smooth, with diverging branches and spines from both ends, which are likewise facetted at their extremities. This type is well shown in the

skeletal-spicules of *Cnemidiastrum Hoheneggeri*, Zitt. (Fig. 4, *c*), from Upper Jurassic strata at Cracow, and in species of *Aulocopium*, from Silurian strata in Gothland (Fig. 4, *d*). This latter genus has indeed been placed by Zittel in the Tetracladina family, but in the character of its skeletal-spicules it appears to me more nearly to resemble *Cnemidiastrum* than any tetracladine genus. Rarely, also, in some of the Sponges of this family, spicules occur in which three subequal spinous rays radiate from a common centre, thus approximating in form to the tetracladine spicules. Zittel<sup>1</sup> has figured a spicule of this form from *Hyalotragos patella*, Goldf. sp.

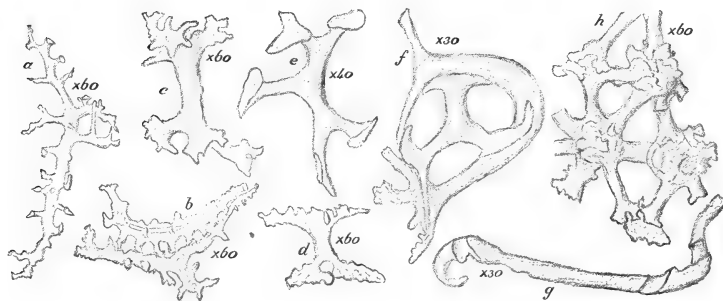


FIG. 4.—Various forms of fossil lithistid spicules belonging to the families of the Rhizomorina, Megamorina, and Anomocladina. (*a*) Branching, spinous, skeletal-spicule of rhizomarine lithistid, *Seliscotho Mantelli*, Goldf. sp. (*b*) Two skeletal-spicules of the same Sponge, showing their mode of union with each other. (*c*) Skeletal-spicule of the rhizomarine Sponge, *Cnemidiastrum Hoheneggeri*, Zitt., from the Upper Jura of Cracow. (*d*) Skeletal-spicule of the rhizomarine Sponge *Aulocopium*, sp. from the Silurian of Gothland. (*e*) Skeletal-spicule of a megamorine Sponge, *Doryderma*, sp. from the Senonian strata of Coesfeld, Westphalia. (*f*) Skeletal-spicules of *Doryderma*, showing their mode of union with each other. (*g*) Skeletal-spicule of the megamorine Sponge, *Carterella*, sp. (*h*) Portion of the skeletal mesh of the Anomocladina Sponge, *Stylospongia*, sp. from the Silurian of Gothland, showing the spicules and their mode of union with each other.

(*b*) *Megamorina*—The skeletal-spicules of this family consist of a straight, or, more frequently, variously curved, elongated main axis, which may either be simple, or may give off irregular branches in different directions (Fig. 4, *e, f, g*). The terminal ends of the main axis and of the branches either form tapering blunted processes, or more usually expand into flat or concave, spoon-shaped surfaces. Both the tapering extensions and the concave expansions may be

<sup>1</sup> 'Studien ueber fossile Spongien,' ii, Taf. 3, fig. 4.



present in the same spicule (Fig. 4, *e*). The spicules of this family are relatively large, and their surfaces smooth. As a general rule, only a simple canal is present, and this only partially, in the main axis of the spicule, but in the great majority of the spicules the canal is not distinguishable in the fossil condition. In the genera *Isorhaphinia*, Zitt., *Carterella*, Zitt., and *Nematinion*, Hinde, the spicules are threadlike and variously notched. In *Carterella* the simple spicule has slender, curved, and twisted extremities (Fig. 4, *g*), whilst in *Isorhaphinia* the spicule has slightly tumid terminations. The greatest diversity of form is shown in the spicules of *Megalithista*, Zitt., *Doryderma*, Zitt., and *Heterostinia*, Zitt., which are curved so variously, and give off lateral and terminal branches in such an irregular manner that it is difficult to find any two spicules closely alike (Fig. 4, *e*, *f*).

(*c*) *Anomocladina*.—The elementary skeleton-spicule of this family of lithistids consists of a thickened, rounded, or compressed central node, from which a variable number of rays (from three to nine) radiate in different directions. The rays are usually smooth, simple, or occasionally furcate, and they terminate in expanded surfaces with even or digitate margins (Fig. 5, *a*). In the genus *Cylindrophyma*,

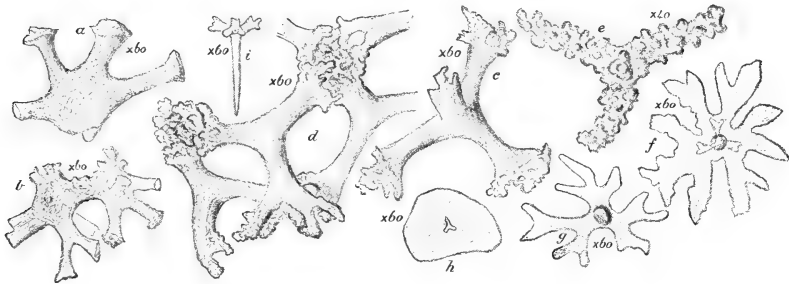


FIG. 5.—Various forms of fossil skeletal- and dermal-spicules of lithistid Sponges. (*a*) Elementary spicule of *Anomocladina* lithistid, *Mastosa Neocomiensis*, Hinde, from the Upper Greensand of Warminster, Wilts. (*b*) Paired or twin spicule of *Anomocladina* lithistid, *Cylindrophyma milleporata*, Goldf., sp. (*c*) Skeletal-spicule of *Tetracladina* lithistid, *Callopegma acaule*, Zitt. (*d*) Skeletal-spicules of *Callopegma Schlanbachii*, Zitt., showing their mode of union with each other. (*e*) Skeletal-spicule of tetracladine lithistid, *Plinthosella squamosa*, Zitt. (*f*) Dermal spicule of lithistid, showing the canals. (*g*) Another dermal spicule, showing the rudimentary shaft. (*h*) Dermal spicule of lithistid, in which no shaft is developed, but traces of the canals remain. (*i*) Dermal spicule of lithistid with furcate head-rays.

Zitt., many of the elementary spicules are of a twin-like character, consisting of two distinct nodes united by a short cylindrical axis (Fig. 5, *b*). From each of

these nodes are given off simple and furcate rays with expanded ends as in the spicules with single separate nodes. In the normal elementary spicules of this family no definite canals have been observed, and even in the spicules of the sole existing representative, *Vetulina stalactites*, Os. Schmidt, canals do not appear to be present; at all events they are not mentioned or figured by Sollas<sup>1</sup> in his recent paper on this species. In the twin spicules of *Cylindrophyma*, however, as first pointed out by Dr. Linck,<sup>2</sup> there is a well-defined simple axial canal in the short axis connecting the two nodes of the spicule, and this canal can occasionally be traced into the central portion of one or other of the nodes, thus proving that the twin nodes and the connecting axis form a single elementary spicule. The canal, however, does not give out branches into the rays of either of the twin nodes. In many of the spicules of *Cylindrophyma Steinmanni*,<sup>3</sup> Linck, there is a gradual diminution in the size of the nodes and the rays proceeding from them, which become also more spinous, and they then resemble spicules of the Rhizomorina family, and can scarcely be distinguished from those of *Cnemidiastrum Hoheneggeri*, for example (Fig. 4, c). On the other hand, the rays given off from the nodes of Anomocladina spicules are very similar to the branches given off from the main axis of Megamorina spicules, and the principal differences in the spicules of these two families consist in the fact that the spicular rays or arms in this latter proceed irregularly from an elongated axis, whilst in the former they proceed from a central node.

Professor Zittel<sup>4</sup> has lately defined the elementary spicule of the Anomocladina family as consisting of simple, straight, or curved rods more or less branched at both ends, and forming nodes by the union of the branched ends of proximate spicules. Judging, however, from the characters of the spicules of the existing *Vetulina stalactites*, O. Sch., in which the central node, and the rays proceeding from it, evidently form a single structure, as figured by O. Schmidt<sup>5</sup> and by Sollas,<sup>6</sup> and from the further fact that in the fossil examples of *Cylindrophyma*, the spicules produced by the disintegration of the skeleton likewise consist of nodes or centra with radiating rays, the evidence seems to be strongly in favour of the theory that these bodies are really the elementary spicules, and not, as suggested by Professor Zittel, compound bodies formed by the union of several simple rod-like spicules.

(d) *Tetracladina*. In this family the skeletal-spicules are four-rayed; the rays or arms diverging from a common, non-inflated centre, at an angle of 120° from each other; they are either smooth (Fig. 5, c), or covered with small tubercles (Fig. 5, e). Near their extremities the rays divide into two or more branches,

<sup>1</sup> 'Proc. Royal Irish Academy,' 2 ser., vol. iv, No. 4, p. 486.

<sup>2</sup> 'Neues Jahrb., &c.,' 1883, ii Band, 1ster Heft, p. 59.

<sup>3</sup> Ibid.

<sup>4</sup> 'Neues Jahrb., &c.,' 1884, Band ii, p. 75.

<sup>5</sup> 'Die Spongien des Meerbusen von Mexico,' p. 19, pl. ii, fig. 9.

<sup>6</sup> 'Proc. Royal Irish Academy,' 2 ser., vol. iv, p. 486, pl. iv.

and these again subdivide into minute twig-like extensions, which are beset with tubercular nodes and swellings. The spicular rays are usually subequal in length; in each there is an axial canal, which in some cases subdivides, and extends into the main divisions of the ray, but cannot be traced into the minute extensions. Typical spicules of this family are present in the genera *Siphonia*, Park., *Phymatella*, Zitt., and the existing *Discodermia*, Bocage. In *Plinthosella*, Zitt., *Spongodiscus*, Zitt., and *Phymaplectia*, Hinde, the skeletal-spicules are less regularly developed, the rays are often very unequal in length, and diverge from each other at unequal angles, the branches terminate obtusely, and the entire spicule is thickly covered with rounded tubercles (Fig. 5, *e*). Some of the skeletal-spicules of *Rhagadinia* have one of the four rays reduced to a rounded knob, and the other rays are partially annulated.

In many lithistid Sponges the spicules forming the stem and root-like appendages of the Sponge differ from those of the body-portion, the modification generally resulting in an elongation of the rays.

*Dermal Spicules of Lithistids.*—In addition to the skeletal-spicules, on the characters of which the four families above mentioned are based, there are also in most, if not all, lithistid Sponges, modified spicules forming the outer surface of the Sponge, which in many instances depart widely in form from the skeletal-spicules. Some of these are distinctly tetractinellid, and are precisely similar in form to the trifid spicules with horizontally-expanded head-rays, which have already been referred to (Fig. 3, *d*). Thus in the genus *Doryderma*, with its large, irregular skeletal-spicules, the dermal spicules are minute trifid spicules with short, simple, or furcate head-rays. The dermal spicules in some Rhizomorina Sponges are of the same general character as those of the skeletal forms, but of much smaller proportions, and with more closely arranged branches. In others, as in *Pachinion*, for example, these are mingled with trifid spicules with horizontally-expanded head-rays. These latter are also present in the tetractinellid genus *Callopegma*, as well as in other Sponges of the same family.

In other more specially modified dermal spicules, the primary head-rays of the trifid spicules become flattened out horizontally, and either divide and subdivide so as to form a filigreed expansion (Fig. 5, *f*), or they are united into a circular or lobate disc, in which the individual rays altogether disappear, though the relations of the spicule are still shown by the presence of three minute canals in its centre, indicating its origin from a simple trifid spicule (Fig. 5, *h*). In the filigreed forms the canals only extend to the first or second subdivision of the rays (Fig. 5, *f*). In these dermal spicules there is a minute central ray or shaft, which extends at right angles to the expanded head. The dermal spicules in the genus *Plinthosella* are minute, delicate, oval, lath-shaped or irregular laminæ, in which neither canals nor vertical shafts are developed.

4. HEXACTINELLID SPICULES.—The typical spicule of this group has six equal rays radiating from a common centre, at right angles to each other, thus with three equal axes. Modifications of the type form occur through the unequal development of one or more of the individual rays (Fig. 6, *b*), which may be either extended or reduced, or even aborted altogether. Thus spicules frequently occur in which one ray is absent, so that a nail-shaped form results, with four rays in one plane, and the unpaired ray at right angles to it (Fig. 6, *c*). In other cases,

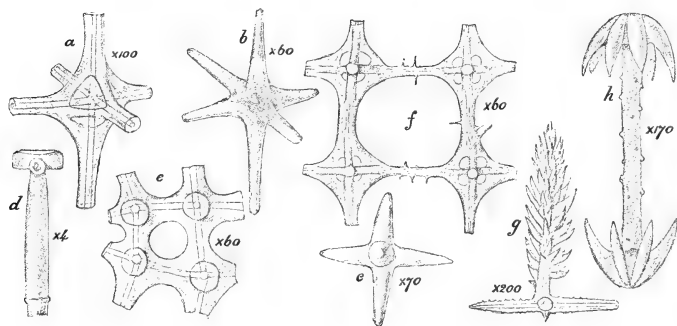


FIG. 6.—Different forms of fossil hexactinellid spicules and fragments of spicular mesh. (a) Spicule with lantern or octahedral node, showing the extension and union of the canals of the different rays in the centre of the node. (b) Simple detached spicule with rays of unequal length and slightly inflated compact node, *Hyalostelia fusiformis*, Hinde. (c) Detached nail-shaped spicule in which only five rays are present. (d) Spicule of *Receptaculites occidentalis*, Salt. (e) A fragment of the skeletal mesh of *Sestrodiction convolutum*, showing the compact nodes and the apparent continuity of the canals between the nodes. (f) A fragment of the skeletal mesh of *Caloptychium agaricoides*, Goldf., showing the lantern or octahedral nodes. (g) Plumose flesh-spicule. (h) Amphidisc flesh-spicule.

the vertical ray of the spicule is reduced to a rounded stump, as in some of the spicules of *Hyalostelia Smithii* (Pl. VI, figs. 1, 1, *a*). By the reduction of one axis the spicule becomes cruciform, as in *Protospongia* (Pl. I, figs. 1, *a*, 2, *a*). The reduction of the number of rays may even proceed so far as to leave a single elongated rod or fusiform axis, not to be distinguished externally from a spicule of the monactinellid type, but its real character is shown by the occasional slight development, in one portion of its length, of the transverse axial canals. As a general rule the spicular rays are simple and smooth (Fig. 6, *b*), but in some cases they bifurcate as in *Spiractinella* (Pl. VIII, figs. 1, 1 *c*), and this subdivision may be carried to

such an extent that the spicule appears stellate (Pl. VIII, figs. 1 *g*, 1 *h*). The rays are not infrequently more or less covered with minute spines or even moniliform. In the abnormal family of the *Receptaculitidae*, the distal or external ray of the spicules is modified into a horizontally extended polygonal plate (Pl. IV, fig. 2), immediately beneath which are the four transverse rays (Pl. IV, fig. 2, *d*), whilst the proximal ray may be either greatly reduced, or normally tapering and pointed, or connected with an internal plate as in the genus *Receptaculites* itself.

In the spicules which serve for anchoring the Sponge to the sea-bottom, one ray is extremely elongated, reaching to a length of several inches, and at its distal extremity the other four rays are developed in the form of small recurved hooks (Pl. VI, figs. 2, *e—k*).

The junction of the rays at the central node in hexactinellid spicules may be formed by their simple union, or there may be a sub-spherical inflation, or from each ray there are given off near the central node short processes or balks, which pass obliquely to the proximate rays and form the outlines of a regular octahedron (Fig. 6, *a, f*). The rays, in greatly diminished thickness, serving merely as sheaths to the axial canals, are continued into the centre of this hollow octahedron, where they unite together. This peculiar modification of the spicular node was first noticed by Toulmin Smith in the Ventriculites from the Upper Chalk; it occurs also in the Jurassic genus *Pachyteichisma*, Zitt., and in many other fossil genera, and also in the recent *Myliusia*, Gray. Such nodes are termed octahedral or lantern, whilst the ordinary nodes are known as simple or compact.

In all complete hexactinellid spicules there is an axial canal in each ray, and the six branches unite together in the centre, both of the spicules with simple, and those with octahedral nodes. The presence of these canals serves to indicate individual spicules, even where a subsequent deposition of silica has completely masked the form of the spicule by merging it in a common extended membrane, as in the dermal layer of many Sponges of this group.

In addition to the skeletal-spicules, the so-called flesh-spicules are largely developed in recent hexactinellid Sponges, but, as already mentioned, their extreme rarity in the fossil state renders them only of subordinate interest to the palæontologist. They are usually of far smaller proportions than the skeletal-spicules, and exhibit a great variety of forms, which, however, in the majority of cases, can be recognised as modifications of the typical six-rayed spicule of the skeleton.

Two characteristic flesh-spicules recently discovered in pre-Miocene strata in New Zealand are shown in Fig. 6. In one (*g*) known as "plumose" or "pinulus," the four transverse rays are relatively small, whilst the fifth ray is unusually elongated and is thickly covered with upward-projecting spinous processes. In the other (*h*) or amphidisc spicule, a cylindrical rod has, at both ends, an umbrella-

shaped disc with several incurved rays. The derivation of this form from the normal hexactinellids is not apparent; it has been suggested by Schultze, however, that the incurved rays are only secondary processes of the nature of spines.

5. OCTACTINELLID SPICULES.—In typical spicules eight rays are present, six of which radiate in a horizontal plane from a common, slightly expanded centre at equal angles from each other, whilst the other two rays form a vertical axis (Pl. IV, figs. 8, *a—c*). This normal type is not, however, of such frequent occurrence as the modification, in which the rays forming the vertical axis are either reduced to small blunt knobs or altogether absent (Pl. I, figs. 7, *a, b, c*). In a single instance an abnormal spicule occurs in which only three of the horizontal rays are developed (Pl. I, fig. 7, *d*). The rays of these spicules are uniformly simple; the horizontal ones appear originally to have been equal in length, and they usually terminate obtusely. In weathered examples, open furrows are exposed on the surface of the rays, indicating the presence of canals. These spicules have been recognised in only a single genus, *Astræospongia*, F. Roem. By Ferdinand Roemer<sup>1</sup> the spicules were regarded as only normally possessing six rays, but Zittel<sup>2</sup> pointed out the presence of a vertical axis in addition to the horizontal rays. By this latter author, however, *Astræospongia* has been placed with the Lyssakine hexactinellids, but the number and disposition of the spicular rays differ so markedly from those of hexactinellid spicules that it is difficult to understand how they can have been derived from the hexactinellid type, and it seems preferable to regard them as belonging to a distinct sub-order.

6. HETERACTINELLID SPICULES.—The above name is proposed for skeletal-spicules with a variable number of rays, ranging from six to thirty, extending from a common centre at different angles. In one genus, *Tholiasterella*, the spicules possess from six to nine rays, projecting nearly horizontally from a central disc, and a single ray extending at right angles from the centre of the disc. The rays may be equal or unequal in length, usually simple, tapering, and blunted, and with numerous projecting warts on their upper surfaces (Pl. VII, figs. 1, *c—g*, 2, *a—d*). In the genus *Asteractinella*, one form of skeletal-spicule has from eight to twenty rays radiating in different directions from a common centre. One of these rays is usually longer and more prominent than the others, which are unequal in size (Fig. 7, *a*); in another form of spicule there are as many as thirty rays, the greater number of which are disposed side by side and partially amalgamated, so as to form a nearly horizontal disc; on the under surface of this there are three or four rays diverging at various angles (Pl. VIII, figs. 3, *e, f*). Owing to the large size and thickness of the rays, it has not been practicable to determine the character of the axial canals. These spicules appear to fundamentally differ from the pre-

<sup>1</sup> 'Lethæa Pal.,' 1 Th., p. 314, 1880.

<sup>2</sup> 'Studien ueber foss. Spongien,' i, p. 59, 1877.

ceding types, and as there are no traces of their derivation from any of them it is necessary to place them in a distinct group.

There are also some other forms of fossil multiaxial siliceous spicules, most of which, if not all, belong to the dermal layer of various Sponges, and differ very widely from the skeletal-spicules of the body of the Sponges to which they belong. Of these the most common are the kidney-shaped or sub-spherical forms which build the outer crust of *Geodia*. These have been supposed by Oscar Schmidt to consist of a radial agglomeration of minute uniaxial spicules (Fig. 7, *b*, *c*). Others are the so-called stellate (Fig. 7, *f*), and globo-stellate spicules (Fig. 7, *d*, *e*), in which a variable number of conical rays project either from a central point or from a rounded nucleus. Another widely-distributed spicule has the form of a delicate

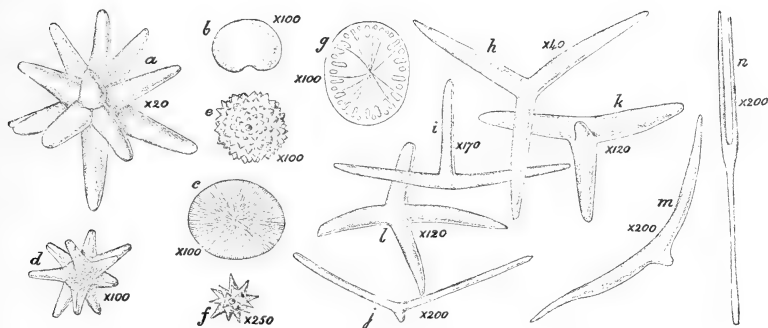


FIG. 7.—Different forms of fossil siliceous heteractinellid and multiaxial spicules and also spicules of fossil calcisponges. (a) Spicule of *Asteractinella expansa*, with twelve unequal rays proceeding from a common centre. (b) Kidney-shaped spicule of the dermal layer of *Geodia*. (c) Another dermal spicule of *Geodia*, showing its composition of apparent spicular rods. (d) Globostellate spicule in which there are traces of canals in each of the rays. (e) Globate spicule with a surface covered by minute spines. (f) Stellate spicule, probably of the dermal layer of a tetractinellid Sponge. (g) Thin elliptical disc with canals radiating from the centre; probably a dermal spicule, named *Stelletites callodiscus*, Carter. (h) A three-rayed equiangular and equiradiate spicule of fossil calcisponge. (i) A three-rayed sagittate spicule, with two equal, paired rays, and one ray, the basal, shorter than the other two. (j, m) Three-rayed spicules, with the basal ray only slightly developed; from the fibre of *Tremacystia D'Orbigny*, Hinde. (k) Four-rayed sagittate spicule with blunted apical ray, from the same Sponge. (l) A four-rayed spicule, showing the apical ray. (n) Three rayed (tuning-fork) spicule, in which the paired rays are nearly parallel with each other.

elliptical disc, bordered by minute flask-shaped cavities, and a series of canals radiating from the centre to near the margin. This has been termed *Stelletites callodiscus*, Carter, but it is not yet definitely known whether it really belongs to a tetractinellid Sponge.

## SPICULES OF FOSSIL CALCISPONGES.

The spicules of calcisponges are much less varied in form, and likewise of much smaller proportions generally than the skeletal-spicules of fossil siliceous Sponges. The fossil examples, so far as at present ascertained, differ but slightly in form and size from those of recent Sponges of this group, but there is a special difficulty in studying them, since it is an extremely rare circumstance to obtain them detached, and their individual outlines can seldom be seen complete in microscopic sections of the fibres in which they are interlaced. Notwithstanding this drawback many of the modifications of the chief types of these spicules, which have been so exhaustively described by Haeckel in his "Kalkschwämme," can be recognised in fossil calcisponges.

1. Simple uniaxial spicules. These in microscopic sections can scarcely be distinguished from portions of three-rayed spicules, more particularly when the basal ray of these latter is only slightly developed. Dunikowski<sup>1</sup> has described fusiform spicules in *Elasmostoma* and *Pachytilodia* with pointed and rounded extremities, and *Pharetrospongia Strahani*, Sollas, seems to be entirely composed of straight or slightly curved uniaxial spicules.

2. Three-rayed spicules. In the simplest form or "regular" spicules, the rays are in the same plane and the rays and angles are equal (Fig. 7, *h*). These have been met with in a detached condition in tertiary deposits at St. Erth,<sup>2</sup> Cornwall, and at Goes in Holland, and forming the dermal layer of *Sestrostomella clavata*,<sup>3</sup> Hinde, from the Upper Greensand of Warminster. In the "sagittate" spicules two of the rays are paired and equal, and the third or basal ray may be either longer or shorter than the other two (Fig. 7, *i*). In spicules of this type, which are abundantly present in the fibres of *Tremacystia*, Hinde, *Corynella*, Zitt., and *Rhaphidonema*, Hinde, the paired rays form a very open angle or a regular curve, in the centre of which on the convex side is a small blunt projection representing the basal ray (Figs. 7, *j*, *m*). In another abnormal three-rayed sagittate spicule, occurring in *Sestrostomella*, Zitt., and also in the recent *Leucetta pandora*, Haeck., the paired rays are nearly parallel with each other and the basal ray extends backwards, so that the spicule is similar in form to a tuning-fork (Fig. 7, *n*). In the "irregular" three-rayed spicules all the rays and the angles are unequal.

The axial canal in the spicules of fossil calcisponges can very rarely be detected, but traces of its presence have been noted by Dunikowski in spicules of *Elasmo-*

<sup>1</sup> 'Palæontographica,' Bd. xxix, p. 11.

<sup>2</sup> 'Quarterly Journ. Geol. Soc.,' vol. xlii, p. 214.

<sup>3</sup> 'Ann. and Mag. Nat. Hist.,' vol. x, 1882, p. 202, pl. xii, fig. 25.



*stoma*<sup>1</sup> from the Cenomanian of Essen, and I have also observed it in detached spicules of *Leuconia* from the Pliocene beds of St. Erth.

3. Four-rayed spicules. These may be described as three-rayed spicules in which an additional ray radiates from the point of junction of the three rays either at right angles or obliquely. This fourth, or apical ray as it has been termed by Haeckel, is, in the fossil forms in which I have noticed it, frequently shorter than the three facial rays of the spicule (Fig. 7, *k*). Four-rayed spicules are present in the dermal layer of *Tremacystia D'Orbigny*,<sup>2</sup> Hinde, and possibly in the dermal layer of other fossil calcisponges as well, but unless the spicules can be isolated it is difficult to determine whether a fourth ray is present or not. Four-rayed spicules are also present in the fibres of *Sestrostomella clavata*,<sup>3</sup> Hinde; in these the rays are curved.

#### THE DISPOSITION OF THE SPICULES IN THE SKELETON.

The manner in which the elementary spicules, whose forms have just been described, are combined together to form the skeleton of the Sponge is very varied in the different groups. According to the nature of this union so is the capacity of the Sponge to resist the disorganizing influences of fossilization, and it probably explains the rarity in the fossil state of certain groups of Sponges which are extremely abundant in the present seas. We proceed to consider first the skeleton of siliceous Sponges.

*Monactinellidæ* and *Tetractinellidæ*. In these two groups, which form the large majority of existing siliceous Sponges, the spicular elements of the skeleton are not organically fused together, but are held in their natural positions by an envelopment of a horny substance known as spongin. In some Sponges this connecting substance is reduced to a small amount, which merely surrounds the terminal ends of the spicules, whilst in others the spicules are completely enveloped by it, and thus held together so as to form a meshwork of fibres, in which they are arranged parallel with each other, or they may be grouped in bundles which branch and anastomose, or radiate from the base to the summit of the Sponge. As this connecting horny substance inevitably decays on the death of the Sponge, the spicules become detached and fall apart, and only under very exceptional conditions of preservation does the skeleton retain its natural form in the fossil state. As a matter of fact, entire Sponges of these groups, or even connected fragments of the skeleton, are of the rarest occurrence,

<sup>1</sup> Op. cit., p. 12.

<sup>2</sup> 'Ann. and Mag. Nat. Hist.,' S. 5, vol. x, p. 192, pl. xi, figs. 1—8.

<sup>3</sup> Id., pl. xii, fig. 16.

though their detached spicules are sometimes sufficiently numerous to form whole beds of rock, as in the Upper Greensand<sup>1</sup> of the Isle of Wight and elsewhere.

Of the few fossil forms which have been discovered may be mentioned the genus *Haplition*, Young and Young, from the Carboniferous strata of Scotland, in which the acerate spicules are closely arranged into anastomosing fibres (Plate V, figs. 1, 2); *Opetionella*, Zitt., from Cretaceous strata, in which the large acerate spicules are disposed side by side to form a thick lamina, and *Scoliorhaphis*, in which the spicules form meandriform laminæ. In a few instances Sponges of these groups have been enclosed in flints, so that the spicules retain their natural arrangement. In *Pachastrella*, O. Schmidt, the spicules are loosely aggregated together, without any apparent order, so as to form a thick wall. Entire examples have been preserved in the Upper Chalk of Flamborough, Yorkshire. In these and the other Sponges mentioned, the spicules, originally only held together by the spongin, are now for the most part lightly cemented and fused together by a secondary deposition of silica, produced during fossilization from a partial solution of the spicules themselves.

The polyaxile stellate, globostellate, and discoid spicules, which form the dermal layer in some tetractinellid Sponges, are, like the skeletal-spicules in these Sponges, merely held together in their natural position by the soft structures of the Sponge, and they have hitherto only been met with detached in the fossil condition.

*Lithistidæ*.—In this sub-order also the skeletal-spicules in their natural condition are not organically united, but the terminal extremities of the spicular rays are firmly linked together in various ways, so as to produce a resistant structure; owing to which, and to the further fact that the walls of these Sponges are often of considerable thickness, entire examples are of frequent occurrence in the fossil state. Their detached spicules are, however, extremely abundant in certain strata, thus showing that in many instances the union of the spicules has not been sufficiently strong to resist disintegration of the skeleton.

In the Tetracladina family the spicules are united together by the interlocking of the tubercular extremities of the twig-like subdivisions of their rays with those of proximately adjoining rays, so that a prominent rounded or oval node is produced by their combination, as in *Callopegma* (Fig. 5, *d*). These twig-like extensions of the rays are so intricately intertwined together that it is almost impossible to separate them without fracture of the more delicate portions. The skeletal mesh thus formed has irregular oval or polygonal interspaces. The spicular rays bounding the canals are deflected so as not to protrude into their channels, but there does not appear to be a specially modified membrane lining their walls.

<sup>1</sup> "Beds of Sponge Remains in the Lower and Upper Greensand of the South of England," 'Phil. Trans.,' part ii, 1885, p. 403.

In *Plinthosella*, Zitt., and *Phymaplectia*, Hinde, the spicules unite together by the interlocking of the tubercles on their lateral surfaces (Fig. 5, *e*) as well as terminally, without forming prominent nodes, thus showing an approximation to the mode of union in the Rhizomorina family.

In the Megamorina family there are two distinct modes in which the skeletal spicules unite together, and both may take place in the same Sponge. In one, the spicules and their branches are twisted round each other almost in the same manner as the strands of whipcord. The spicules may be merely twisted at their ends, or throughout their length; and owing to the lateral and terminal notches (Fig. 4, *g*) they are very closely fitted together, so as to produce a fibrous meshwork. This mode of union is typically shown in *Carterella*, Zitt., and *Isorhaphinia*, Zitt. The second mode is exemplified in spicules, in which the branches terminate in flattened, concave, spoon-shaped expansions (Fig. 4, *e*), which closely and evenly fit, and clasp the surfaces of adjoining spicules, and thus form a meshwork of open irregular interspaces. This kind of union is well shown in *Doryderma*, Zitt. (Fig. 4, *f*), *Heterostinia*, Zitt., and in the recent *Lygidium*, Os. Schmidt.

In the Anomocladina family the union of the skeletal spicules takes place, in some respects, in the same manner as in the Megamorina family described above, that is to say, the terminal ends of the spicular rays are similarly furnished with expanded surfaces (Fig. 5, *a, b*), which are firmly attached to the central nodes, and occasionally to the rays of adjoining spicules, thus forming a mesh apparently composed of star-shaped bodies, whose rays are all united together (Fig. 4, *h*). These stellate bodies of the connected skeleton are thus of a compound character, for in each there is the node and the rays proper to it, forming the elementary spicule, and also other rays belonging to adjoining spicules whose terminal expansions are firmly attached to the node. This union is usually so close that it is not practicable to determine in the connected skeleton the rays proper to the node from those which are merely adpressed to it (Fig. 4, *h*). In some instances, in the skeleton of *Astylospongia*, the spicular rays converge to a point in which no central node is present for them to clasp, but they terminate in precisely the same way as if the node were in the proper position, and are thus grouped round a sub-spherical cavity. In some examples of *Cylindrophyma*, the rays project from the node at right angles to each other, and the connected skeleton has quadrate or subquadrate interspaces, singularly resembling the mesh of hexactinellid Sponges, for which it has sometimes been mistaken. Typical examples of the skeleton of Anomocladina Sponges are shown in *Cylindrophyma*, Zitt., *Astylospongia*, Ferd. Roem. (Fig. 4, *h*), and the recent *Vetulina*, Os. Schmidt.

The skeletal-spicules of the Rhizomorina family are united together by the close adpression of the minute facets terminating the numerous branches and spinous processes of the spicules, to the main axis and branches of adjoining

spicules (Fig. 4, *b*). As these facets are very numerous, and radiate in all directions from the main axis of the spicules, they form by their union an extremely intricate meshwork with minute irregular interspaces. In some instances the spicules thus united produce anastomosing fibres with open interspaces, in which the circulation is carried on, as, for example, in *Pachinion*, Zitt.; in others, as in *Seliscothion*, Zitt., they form thin vertical lamellæ.

The spicules of the dermal layer in lithistid Sponges are arranged so that the small vertical ray penetrates into the wall of the Sponge, whilst the horizontally extended head-rays cover the outer surface, frequently overlapping each other, thus forming a smooth covering with only microscopic interspaces. They are not organically attached to each other, or to the skeletal spicules, and it is very seldom that they have been preserved *in situ* in the fossil state. In some cases the dermal spicules appear to have extended over the cloacal surface as well as over the exterior of the Sponge. In the genus *Doryderma*, the trifold spicules of the dermal layer are tightly packed, with their shafts parallel to each other, into the open meshes of the skeletal-spicules, and their head-rays project, like arrows in a quiver.

*Hexactinellidæ*.—In this division the six-rayed spicules are disposed so that their rays overlap each other, and produce a framework which, when regularly developed, has quadrate or subquadrate boundaries. The spicules may be simply held in position by the sarcode or fleshy portion of the Sponge, or they are united organically together by a common siliceous sheath. Fossil examples of those Sponges in which the spicules are not organically fused together are very rare, though the detached spicules are extremely abundant. Judging by existing forms of these Lyssakine Sponges, the spicules are generally arranged into elongate, loose fasciculate fibres or open tissues, which in some genera, as in *Euplectella*, for example, cross each other in regular lines. Not strictly in all cases are the spicules free from each other, for they are sometimes soldered together laterally, and at the crossing of some of the larger rays, by a deposit of silica. In many recent Lyssakine Sponges the spicules of the dermal layer have the same regular arrangement as those of Dictyonine Sponges, and form a meshwork with quadrate interspaces, but the spicules are not fused together. A fragmentary example of this is shown in *Hyalostelia Smithii* (Pl. VI, fig. 1). The elongated spicules of the anchoring rope of this group of Sponges are disposed either parallel to each other, so as to form rounded or compressed fascicles (Pl. I, fig. 3; Pl. VI, figs. 2, 3 *d*), or they extend singly through the rock. Though the component spicules of these ropes are not organically attached together, yet they are found in close contact with each other for considerable distances, and this undisturbed arrangement may probably be owing to the circumstance that these anchoring ropes were embedded in the mud during the life of the Sponge, and were thus preserved from disintegration after its death.

In the Dictyonine division of hexactinellids, the overlapping rays of adjoining spicules are enclosed and united with each other in a common, regular, even coating of silica, so as to form a continuous fibrous meshwork, the faces of which may be squares (Fig. 6, f) or polygons. The individuality of the component spicules in this continuous meshwork cannot be recognised on the exterior, but it is shown by the internal canals of the rays, which can be seen to extend from each of the nodes of the mesh and to overlap those proceeding from adjoining nodes. In some instances the internal canals appear to be continuous from node to node, as in *Sestrodiction* (Fig. 6, e), but this probably arises from the breaking down in the fossilization of the delicate partitions dividing them. The regular quadrate or cubical arrangement of the spicular meshwork is frequently interrupted by the irregular interposition of spicules, the rays of which may become fused to the nodes or centres of other spicules, or even to the lateral portion of their rays, producing a confused meshwork, in which the original hexactinellid form of the spicules is largely masked. This irregular structure is more especially developed where the spicular structure is minute, and there are numerous canals in the sponge-wall, as in *Leptophragma*, Zitt., and *Coscinopora*, Goldf.

The union of the spicules in the dermal layer of hexactinellids in most cases differs very considerably from that of the interior meshwork of the skeleton. This dermal layer, in some instances, consists of a delicate siliceous membrane with circular or polygonal apertures. No individual spicules can be seen on the exterior of this membrane, but when examined by transmitted light the membrane is seen to consist of a framework of irregularly-scattered four- or six-rayed spicules, the canals of which still remain, and between these the delicate membrane has been deposited. This kind of dermal layer is shown in *Craticularia*, Zitt., *Guetardia*, Mich., *Plocoscyphia*, Reuss, and other genera. It is not merely limited to the outer and cloacal surfaces of the Sponge, but frequently lines the canals and inter-canals. In another modification, the dermal layer consists of large cruciform or five-rayed spicules, irregularly disposed and soldered together where the rays touch or cross each other; sometimes also connected by siliceous balks or rods or even by a siliceous membrane, as in the genus *Cypellia*, Pom. Sometimes also the skeletal mesh of the Sponge is irregular, whilst the spicules of the dermal layer form a very regular connected quadrate meshwork, as in *Casearia*, Quenst. In the existing genus *Sclerothamnus*, Marshall (= *Dendrospongia*, Murie), the spicules of the dermal layer are regularly disposed to form a quadrate meshwork, but the rays are not cemented together, and remain free, similar to those of the dermal layer of Lyssakine Sponges; thus in this genus the skeletal mesh is formed by united spicules, and therefore Dictyonine in character, whilst the dermal layer is distinctly Lyssakine. In the Cretaceous genus *Cinctiderma*, Hinde, there is a dermal layer of large spicules forming a regularly

quadrate framework, and the interspaces are filled by numerous irregularly arranged cruciform or five-rayed spicules, the whole forming a smooth, connected, surface membrane. In the enveloping dermal layer of *Cystispongia*, Roem., and *Camerospongia* (D'Orb.), the siliceous membrane is very fine and delicate, and no traces of spicules or of their axial canals can be detected in it.

*Octactinellidæ*.—In this small group, only represented by the genus *Astræospongia*, the skeletal spicules do not appear to have been attached in any way to each other, but they are distributed without apparent arrangement beyond that the stellate disc is generally parallel to the upper surface of the Sponge. The spicular rays rest upon and cross over each other, but without leaving any definite interspaces or canals. There are no indications of a special disposition of the spicules on the outer surface of the Sponge to form a dermal layer.

*Heteractinellidæ*.—The skeletal-spicules in this group appear to have been distributed quite irregularly in the body of the Sponge, their rays interlacing with each other loosely, and the smaller spicules filling in the spaces between the rays of the larger forms. In some instances, fragments of the skeleton are met with in which the spicular rays are lightly cemented together; but this probably results from a secondary deposit of silica during fossilization, like that which occurs in the tetractinellid *Pachastrella* from the Chalk of Flamborough.

In the dermal layer of some of the Sponges of this group the spicules are disposed so that their disc-rays interlace and fit into notches in adjoining rays (Pl. VII, fig. 1 *b*), whilst the radial ray projects into the interior of the sponge-wall (Pl. VII, figs. 1, 2). The rays also are, in some instances, partially fused together, in others they are compressed and completely united with those of adjoining spicules, so that there are only small oval apertures in the dermal layer (Pl. VII, fig. 3).

*Calcisponges*.—In the large majority of fossil calcisponges the skeletal-spicules are arranged side by side in close contact with each other, so as to form cylindrical fibres, which anastomose together. The spicules do not appear to be organically attached or fused together in any way, and it is somewhat surprising that the fibres thus composed should have in so many instances resisted disintegration. In some cases there is a relatively large axial spicule in the centre of the fibre, which is enveloped by smaller filiform spicules; whilst in others the spicules are throughout equal or subequal. In one genus (*Protosycon*) the spicules appear to have the same arrangement as in the existing *Sycones*, that is to say, they form a series of horizontal tubes.

The four-rayed spicules of the dermal layer in some instances are irregularly disposed over the outer surface of the Sponge, and the apical ray is directed into the sponge-wall; in other cases the spicules are irregularly and closely mingled together, so as to produce an apparently compact, smooth, or wrinkled membrane.

## SYSTEMATIC POSITION AND CLASSIFICATION.

The position of Sponges in the animal kingdom may now be said to be decided generally in favour of their belonging to the Metazoa, but there is not the same unanimity of opinion as to whether they should be included in the Cœlenterate type or placed independently as the lowest division of the Metazoa. It is a question which can only be decided by a consideration of the embryological development and the soft structures of the organism, and no light whatever is thrown on it by the fossil forms. So long since as 1867, Sponges were regarded as Cœlenterata by Leuckart, and this view has gradually been accepted by most authorities on the subject till within a recent period; but at the present time the opinion that they represent a type distinct from the Cœlenterata seems to be most in favour. Similar differences of opinion also exist with respect to the classification of existing Sponges, and nearly every recent author on the subject propounds a distinct system, differing alike in the main as well as in the subordinate divisions from those previously advanced. Attempts have even lately been made to arrange the Sponges according to the characters of their soft structures, but it need hardly be said that any system on this basis would be entirely useless for fossil forms, in which only the mineral portions of the skeleton are available for purposes of classification.

As regards the classification of fossil Sponges, it seems scarcely necessary to mention the various systems in use previous to that brought forward by Professor Zittel, since they are now regarded as obsolete, and possess a mere historical interest. The main features of Zittel's classification, which I propose to adopt with some modifications, depend on the characters of the skeletal elements of the organism. The following list shows the leading divisions.

## CLASS: SPONGIÆ.

Order I. MYXOSPONGIÆ, *Haeckel*.

„ II. CERATOSPONGIÆ, *Bronn*.

## Sub-Order.

	{	1. Monactinellidæ, <i>Zittel</i> .
		2. Tetractinellidæ, <i>Marshall</i> .
		3. Lithistidæ, <i>Os. Schmidt</i> .
„ III. SILICISPONGIÆ		4. Hexactinellidæ, <i>Os. Schmidt</i> .
		5. Octactinellidæ, <i>Hinde</i> .
		6. Heteractinellidæ, <i>Hinde</i> .

„ IV. CALCISPONGIÆ, *Blainville*.

## CLASS : SPONGIÆ.

*Definition.*—Bodies of very variable form, consisting principally of a soft fleshy mass, enclosed by an epithelium of a single layer of cells. The body is penetrated by a system of canals opening into chambers, and communicating with the exterior by numerous smaller apertures or pores, and larger or vents. In the majority of forms the body is supported by a skeleton, which is composed either of horny fibres or of siliceous or calcareous spicules.

## Order I.—MYXOSPONGIÆ.

Sponges without any skeleton, or with only a few scattered siliceous spicules (v. Lendenfeld).<sup>1</sup> Unknown as fossil.

## Order II.—CERATOSPONGIÆ.

Sponges with skeletons of horny fibres, which may contain foreign bodies but not proper spicules. Siliceous spicules rarely present, scattered in the mesodermal tissues (v. Lendenfeld).

No Sponges of this group are definitely known as fossils, the form described as such by Carter under the name of *Dysidea antiqua* being a siliceous monactinellid, whilst the reputed horny Sponges, known as *Spongites*, are of an altogether doubtful character.

## Order III.—SILICISPONGIÆ.

Sponges with skeletons of siliceous spicules, either held in position by the soft portions of the Sponge, or united together in various ways to form skeletal fibres.

## Sub-Order 1.—MONACTINELLIDÆ.

The skeletal-spicules possess a simple unbranched axis. They may be enclosed in distinct fibres or merely held together by spongin. The usual forms are acerate, acuate, cylindrical, or conical. Flesh-spicules of various forms may or may not be present.

Owing to the mode in which the spicules are held together by the fleshy or horny parts of the organism, entire Sponges, or even fragments, are of very rare

<sup>1</sup> "Monogr. Austr. Sponges," 'Proc. Linn. Soc. New South Wales,' vol. ix, 1884, p. 339.



occurrence in the fossil state. Detached monactinellid spicules are, however, very abundant in certain strata, but though many of these most probably belong to the next sub-order, there are others which may undoubtedly be regarded as pertaining to this group. The families of the existing Monactinellidæ are, to a certain extent, based on characters which cannot be applied to the fossil spicules; but the following appear to be represented: Halichondridæ, Desmacidonidæ, Suberitidæ, and Spongillidæ.

#### Sub-Order 2.—TETRACTINELLIDÆ.

Sponges with skeletal-spicules normally of four rays or axes, disposed like the four axes of a regular three-sided pyramid. One ray frequently more developed than the others, so as to form a long shaft. Uniaxial spicules of large size usually present. Skeletal-spicules frequently disposed in fascicles with a radiate arrangement. Spicules held together by spongin. Polyaxonal spicules in the form of stellates, globostellates, and discs frequently present.

Representatives of two at least of the existing families of this sub-order, Geodidæ and Ancorinidæ, are present as fossils, but from their imperfect condition of preservation it is impracticable to determine in most of the fossil forms the characters which distinguish the respective families.

#### Sub-Order 3.—LITHISTIDÆ.

Sponges of a stony character, usually with thick massive walls. Skeletal-spicules either four-rayed or altogether irregular in form, usually branching at their extremities, which terminate obtusely, or with minute expanded surfaces. Spicules firmly united together by the intertwining of their branches, or by the close apposition of their expanded extremities, but not fused together. A surface or dermal layer of trifid spicules or small discs is usually developed, as well as minute uniaxial flesh-spicules. Large skeletal uniaxial spicules occasionally present.

This sub-order has been divided by Zittel into the following four families:

#### Family 1.—RHIZOMORINA.

Skeletal-spicules usually elongate and irregularly branching, with minute projecting spines. Branches terminating in minute facets, which are closely apposed to the axis and branches of adjoining spicules, forming an irregular meshwork or

confused fibres. A canal in the main axis of the spicules. Dermal layer either of spicules resembling those of the skeleton, or of compound trifids.

Family 2.—MEGAMORINA.

Skeletal-spicules large, elongate, smooth, straight or curved, simple, or irregularly branching. A canal in the main axis of the spicule. Branches terminating obtusely or with expanded facets. Spicules united by being intertwined together or by the apposition of their terminal facets, forming an open meshwork. Small spicules of the Rhizomorina type occasionally filling the interspaces of the mesh. Dermal layer of compound trifid, or minute uniaxial spicules.

Family 3.—ANOMOCLADINA.

Skeletal-spicules consisting of a central sub-spherical node, from which a variable number of simple or furcate arms, with slightly expanded terminations, radiate in different directions. In some cases the nodes are in twins connected by a short axis, in which a canal is present, and the rays are partially spined. Spicules united by the apposition of the expanded terminations of the rays to the nodes, and occasionally to the branches, of adjoining spicules, so as to form a regular meshwork.

Family 4.—TETRACLADINA.

Skeletal-spicules of four rays extending from a common, non-inflated centre, approximately at angles of  $120^{\circ}$ . Rays smooth or tuberculated, with branching extremities, which interlock with those of adjoining spicules to form the mesh. An axial canal in each of the spicular rays. The spicules of the dermal layer are either compound trifids, entire or lobate discs, or irregular laminæ, and also minute uniaxial spicules.

Sub-Order 4.—HEXACTINELLIDÆ.

The skeletal-spicules normally consist of six rays, radiating from a common centre, at right angles to each other. An axial canal is present in each ray. The spicules are arranged so that their rays overlap each other and form a lattice-like mesh with cubical or irregular interspaces. They are either united together by a common siliceous envelope, or interlaced and held in position by the soft structures. Two main groups Dictyonina, Zitt., and Lyssakina, Zitt.

## Group.—DICTYONINA.

The skeletal-spicules are normal hexactinellids, whose rays are fused together by a common siliceous envelope so as to produce a firmly-united meshwork, which, when regular, has cubical interspaces. The spicular nodes or centres may be either simple or octahedral. A dermal layer of modified six-rayed spicules usually present. Flesh-spicules may be present or absent.

Family 1.—EURETIDÆ, *Zitt.*

Sponges cup-shaped, cylindrical, turbinate, laminate or branching. Skeletal mesh regular; the spicular nodes simple. The dermal layer consists of a thickening of the exterior layer of the skeletal mesh, occasionally also a delicate meshwork extends completely over the surface, and covers the apertures in the sponge-wall. The structure of the root-appendage similar to that of the body of the Sponge.

Family 2.—COSCINOPORIDÆ, *Zitt.*

Sponges cup-shaped, branching, frequently compressed, or with flange-like walls extending from a centre. Very numerous, simple, straight, blind, radiate canals, which open alternately on both sides of the sponge-wall. Skeletal mesh close, and, owing to the numerous canals, irregular. Spicular nodes usually simple, but occasionally octahedral. Dermal layer, when present, a cribriform membrane.

Family 3.—MELLITIONIDÆ, *Zitt.*

Sponges irregularly globular or branching. Walls completely perforated by tubular canals, resembling the cells of honeycomb. Spicular nodes simple. Meshwork irregular. Dermal layer, a delicate siliceous meshwork which covers also the canal-apertures.

Family 4.—CALLODICTYONIDÆ, *Zitt.*

Sponges cup-, funnel-shaped, or compressed. Spicular mesh large and regular; spicular nodes octahedral. Dermal layer cribriform. No special canals shown in skeleton.

Family 5.—PROTOSPONGIDÆ, *Hinde, n.*

Sponges cup- or funnel-shaped. Skeletal mesh apparently consisting of a single layer of modified hexactinellid spicules, forming quadrate areas of various dimensions. Spicules appear to be embedded in a delicate siliceous membrane.

This family is proposed to include *Protospongia*, Salter, *Phormosella*, Hinde, *Plectoderma*, Hinde, and possibly also some of the forms included under *Dictyophyton*, Hall. The structure of the sponge-wall resembles that of the dermal layer of some of the Sponges of the next family, but, unlike these, no interior meshwork is present. Owing to the imperfect condition of preservation, the nature of the sponge-wall is not clearly shown; by some authors the spicules are believed to be free from each other, and thus of a Lyssakine character.

Family 6.—STAURODERMIDÆ, *Zitt.*

Sponges turbinate, funnel-shaped, cylindrical, rarely branching. Interior skeletal mesh irregular, spicular nodes simple or octahedral. Dermal layer of cruciform or five-rayed spicules forming a regular or irregular framework; in the interspaces a siliceous membrane of smaller spicules.

Family 7.—VENTRICULITIDÆ, *Toulmin Smith (emend. Zitt.)*.

Sponges simple or compound, cup-, funnel- or top-shaped, cylindrical or ramose. Wall in meandrous folds. Spicular nodes octahedral. Radial canals blind. The outer or under surface of the Sponge with elongate apertures or furrows, the inner or upper surface either similar to the lower or with circular vents. Dermal layer a cribriform siliceous membrane. Root-appendage of fasciculate, siliceous fibres, united by transverse extensions, and without axial canals.

Family 8.—MÆANDROSPONGIDÆ, *Zitt.*

Sponges of variable form, consisting of laminate walls in meandrous folds, which anastomose together, frequently forming open tubes. Walls with radiate blind canals, or with the ordinary apertures of the mesh. Inter-canal system always present. Spicular nodes either simple or octahedral. Dermal layer, when present, a continuous cribriform membrane either partially or entirely enclosing the anastomosing walls.

Family 9.—CÆLOPTYCHIDÆ, *Zitt.*

Sponges with flattened or depressed disc-shaped summits supported on short stems. Interior skeleton of thin laminated walls, folded so as to divide the central cavity into radial chambers. Skeletal mesh regular, with relatively large interspaces; spicular nodes octahedral. Dermal layer of the upper surface a siliceous membrane with alternately arranged coarse and fine cribriform areas. The vents on the summits of the ridges of the under surface, occasionally also on the stem.

Group.—LYSSAKINA, *Zitt.*

Skeletal-spicules interlaced and either held in position by the fleshy structures of the Sponge, or exceptionally cemented together irregularly and united by siliceous outgrowths. Spicules often peculiarly modified, their nodes always simple. Flesh-spicules of various forms usually present, also anchoring-ropes of elongated spicules.

Family 1.—POLLAKIDÆ, *Marshall.*

Skeletal-spicules may be simple hexactinellids or forms greatly modified by the reduction or subdivision of the normal rays, also by the unusual development of one or more of the rays. A distinct dermal layer present. Flesh-spicules of varied forms. Anchoring-appendage of elongate spicules, either in bundles or extending singly from the body of the Sponge.

Family 2.—RECEPTACULITIDÆ, *Eichwald*, pars, emend. *Hinde.*

Sponges open cup-shaped, turbinate, sub-spherical and conical, free. The distal ray of the skeletal-spicules modified into a rhomboidal or polygonal plate. The spicules disposed so that the outer plates form a smooth surface of regular oblique, curved, or spiral rows, whilst the four transverse rays mark radial and concentric lines beneath the surface. A perforate inner layer present in one genus.

## Sub-Order 5.—OCTACTINELLIDÆ.

Skeletal-spicules normally of eight rays, six of which are in a horizontal plane, radiating at equal angles from a common centre, whilst the other two rays, which

are frequently reduced or absent, form a vertical axis. Spicules merely held in position by the soft structures of the Sponge. This sub-order is represented by the single genus *Astræospongia*, Ferd. Roemer.

#### Sub-Order 6.—HETERACTINELLIDÆ.

Skeletal-spicules consisting of an indefinite number of rays, varying from six to thirty, radiating from a common centre. The body-spicules irregularly arranged and held in position by the soft structures of the Sponge. The spicules of the dermal layer are interwoven together, and their rays partially or completely fused with each other.

#### Order IV.—CALCISPONGIÆ.

Sponges whose skeletal spicules are composed of carbonate of lime. Spicules either uniaxial, three-rayed, or four-rayed. They are either regularly arranged to form the skeleton, or loosely distributed in the soft tissues, or closely apposed together to form anastomosing fibres. Only two families have up to the present been definitely recognised in the fossil state.

##### Family, PHARETRONES, *Zitt.*

Skeletal-spicules arranged in the form of solid anastomosing fibres. Canals branching irregularly, at times not indicated in the skeleton. Dermal layer forming a continuous smooth or corrugated membrane.

##### Family, SYCONES, *Haeckel.*

Skeletal-spicules very regularly arranged to form transverse simple radial tubes or chambers, which open into a central cloaca. A distinct dermal and cloacal layer present.



## PLATE I.

### Figs. 1, 1 *a*.—*PROTOSPONGIA FENESTRATA*, *Salter*.

Fig. 1.—A fragment of the spicular-mesh of the Sponge-wall, embedded in hard black slate. Natural size. From Menevian strata, St. David's, South Wales. Drawn from the type example of the species, now in the British Museum (Natural History).

Fig. 1 *a*.—A portion of the spicular-mesh of the same specimen, magnified five diameters. The original regular arrangement has been partly broken up, and owing to the cleavage of the rock the angles of the spicules are distorted.

### Figs. 2, 2 *a*.—*PROTOSPONGIA HICKSI*, *Hinde*, sp. nov.

Fig. 2.—The compressed Sponge-wall, traces of which can be seen covering the surface of a slab of dark shale. Natural size. From Menevian strata, Porth-y-Rhaw, St. David's, South Wales. Drawn from the type specimen, in the Woodwardian Museum, Cambridge.

Fig. 2 *a*.—Portion of the spicular-mesh of the same specimen in an imperfect condition. Magnified five diameters.

### Figs. 3, 3 *a*, 3 *b*.—*HYALOSTELIA FASCICULUS*, *McCoy*, sp.

Fig. 3.—Portion of the anchoring-rope of the Sponge, showing the parallel disposition of the component spicules. Natural size. Probably from Llandeilo Rocks. Original in British Museum (Natural History).

Fig. 3 *a*.—Transverse section of the same specimen, enlarged ten diameters.

Fig. 3 *b*.—Portion of the rope, enlarged ten diameters, showing the annular or spiral frills on the spicules.

### Figs. 4, 4 *a*.—*HYALOSTELIA SMITHII*, *Young and Young*, sp.

Fig. 4.—Portion of the rock, showing the size and the distribution of the anchoring-spicules in transverse section. Magnified five diameters. From Ordovician shale at Knockgeiran, near Girvan, Ayrshire. The original specimen in the collection of the author.

Fig. 4 *a*.—A longitudinal section of the rock, showing the spicules, which have been cut through obliquely. The transverse bands in them arise from the replacement of the silica by a mineral of a different aspect. Magnified five diameters.

### Figs. 5, 5 *a*—5 *f*.—*HYALOSTELIA GRACILIS*, *Hinde*, sp. nov.

Figs. 5, 5 *a*—*c*.—Hexactinellid spicules, with the normal number of rays, though mostly imperfect.

Figs. 5 *d*, *e*.—Cruciform spicules, rays all unequal. In 5 *e* they are spinous.

Fig. 5 *f*.—Microspined cylindrical rods, probably belonging to the anchoring spicules of the Sponge. All magnified forty diameters. From decayed Wenlock limestones, Craven Arms, Shropshire. The original specimens in the collection of John Smith, Esq., Kilwinning, Ayrshire.

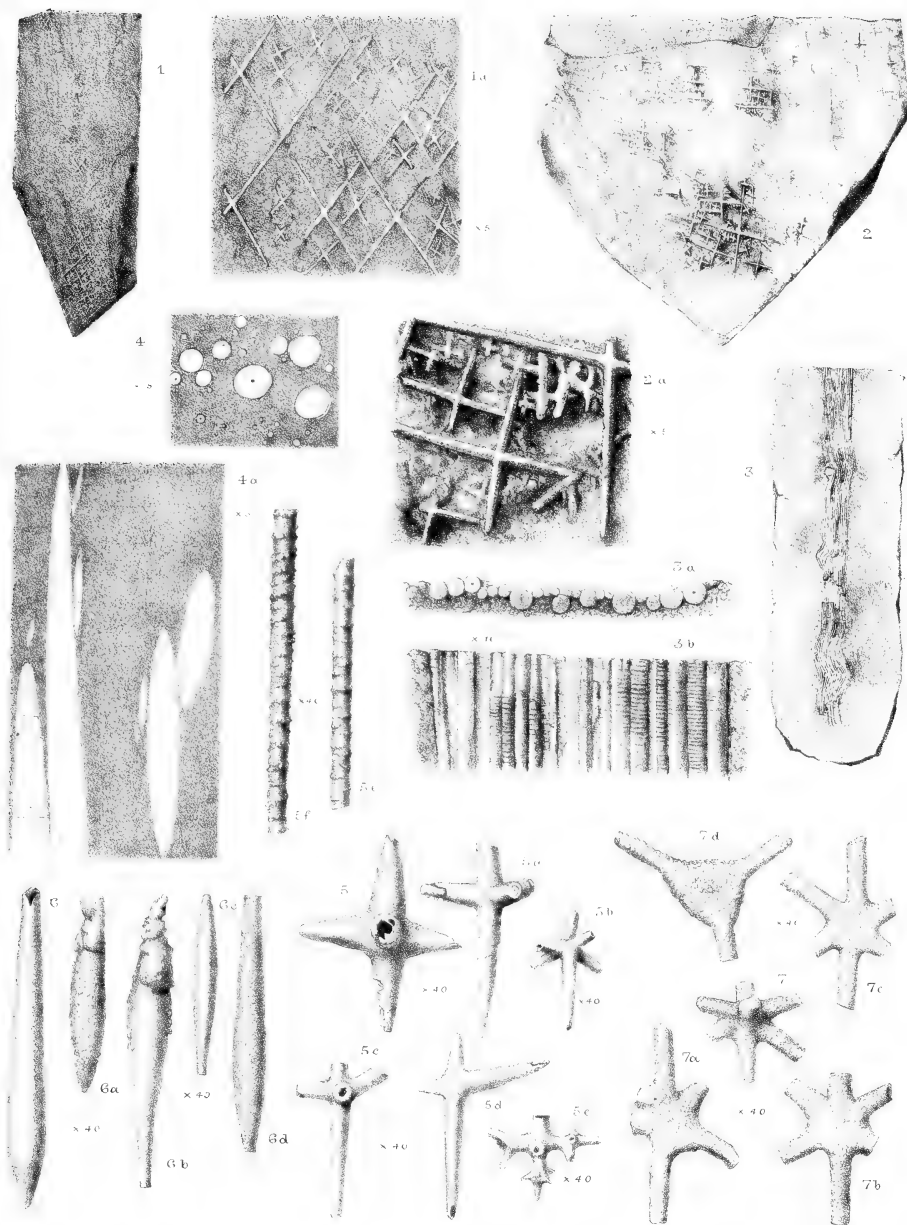
### Figs. 6, 6 *a*—6 *d*.—*ATRACTOSELLA SILURIENSIS*, *Hinde*, sp. nov.

Detached fusiform spicules, referred to this species. The specimens are siliceous; 6 *a*, *b*, are partially encrusted with matrix. Magnified forty diameters. From Wenlock limestones, Craven Arms, Shropshire. The original specimens in the collection of John Smith, Esq., Kilwinning.

### Figs. 7, 7 *a*—7 *d*.—*ASTREOSPONGIA PATINA*, *F. Roemer*.

Detached spicules of this species, the rays in all cases imperfect. In Figs. 7 *a*, *b*, *c*, only the six horizontal rays are present, in Fig. 7 one ray of the vertical axis is developed, whilst 7 *d* represents an abnormal form in which only half the number of the horizontal rays is developed. Magnified forty diameters. From Wenlock shales at Wren's Nest, Dudley, and at Benthall Edge, Shropshire. The original specimens in the collection of John Smith, Esq., Kilwinning.









## PLATE II.

Figs. 1, 1 a, 1 b.—*ISCHADITES KENIGII*, *Murchison*.

Fig. 1.—The cast of a fairly complete specimen, showing the summit aperture and the vertical furrows formed by the transverse rays of the spicules. Natural size. From Wenlock Limestone at Wren's Nest, Dudley. The original specimen in the Woodwardian Museum at Cambridge.

Fig. 1 a.—Compressed cast of a specimen, in which the spicular summit-plates have disappeared, and the transverse rays beneath are shown. Natural size. From Wenlock Limestone, Dudley. The original specimen in the British Museum (Natural History).

Fig. 1 b.—Casts of two entire specimens, and fragments of four others, partially embedded in a slab of hard calcareous shale. The lozenge-shaped depressions are the casts of the spicular summit-plates, and the casts of the transverse rays of the spicules can be seen in most of the depressions. Natural size. From Lower Ludlow Rocks at Ludlow. Drawn from the type of the species, now in the Museum of the Geological Society, Burlington House.

Figs. 2, 2 a.—*ISCHADITES LINDSTRÖMI*, *Hinde*.

Fig. 2.—Cast of the basal portion of a specimen, partially embedded in matrix, showing the concave base, the lozenge-shaped depressions of the spicular summit-plates, and the radial and concentric lines formed by the transverse rays of the spicules. Natural size. Wenlock beds at Malvern. The original specimen in the Natural History Museum, Oxford (Grindrod Collection).

Fig. 2 a.—Cast of the upper portion of an individual, showing the central aperture and impressions of the summit-plates. Natural size. Wenlock beds at Malvern. Original in the Natural History Museum, Oxford (Grindrod Collection).

Fig. 3.—*RECEPTACULITES NEPTUNI*? *Defrance*.

Cast of a portion of the under or outer surface of a specimen on a slab of limestone. The margins of the spicular summit-plates are distinctly crenulated. Natural size. Wenlock Limestone, Malvern. The original specimen in the Natural History Museum, Oxford (Grindrod Collection).

Figs. 4, 4 a—4 c.—*DICTYOPHYTON DANBYI*, *McCoy*, sp.

Figs. 4, 4 a.—Casts of two specimens, partially embedded in an arenaceous matrix, showing in high relief the vertical and transverse ridges formed by the spicules. Natural size. From Upper Ludlow beds at Benson Knot and Brigsteer, Kendal. The original specimens in the Woodwardian Museum at Cambridge.

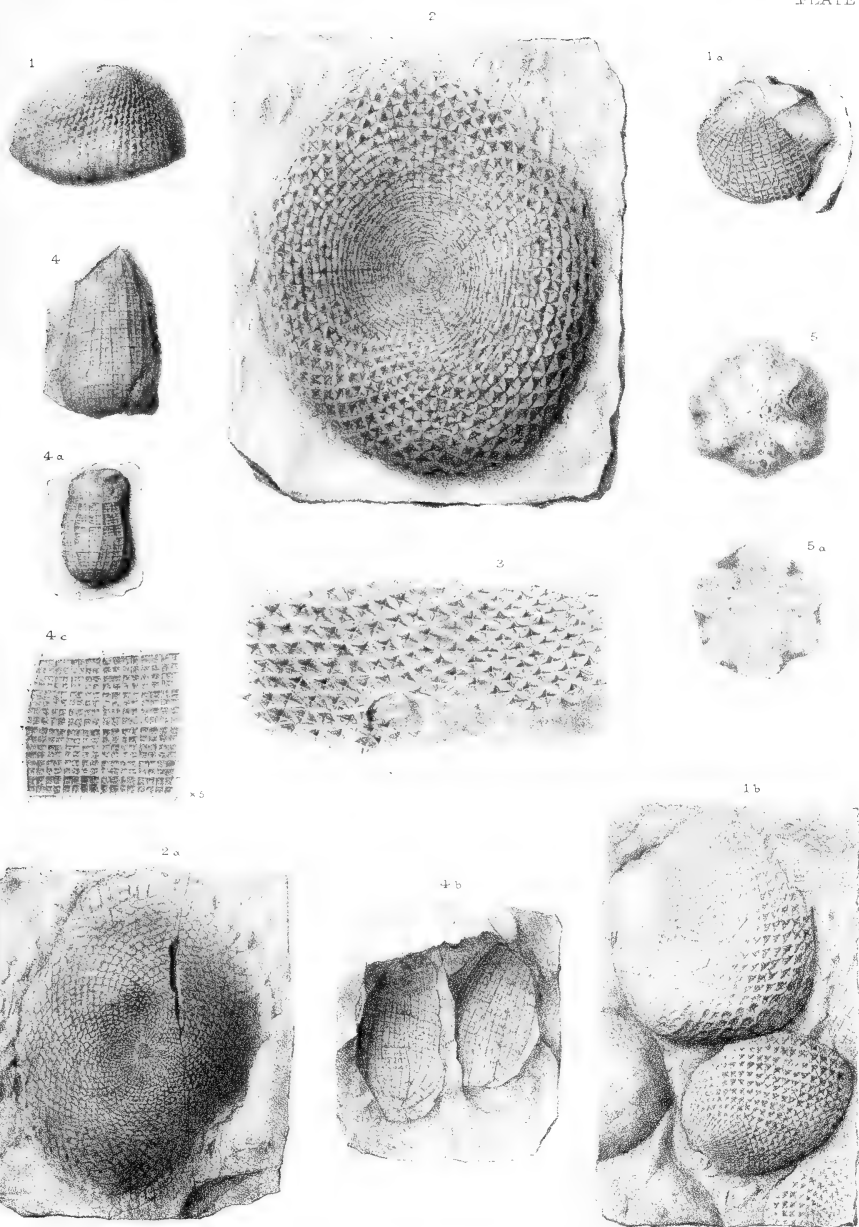
Fig. 4 b.—Casts of two specimens, in an arenaceous matrix, showing the impression of the spicular structures in bas-relief. Natural size. From Lower Ludlow strata at Underbarrow, Westmoreland. The original specimen in the Museum of the Geological Society, Burlington House.

Fig. 4 c.—Portion of the surface of 4 a, enlarged five diameters, showing the larger and subordinate quadrate areas of the spicular mesh.

Figs. 5, 5 a.—*ASTYLOSPIGIA INCISOLOBATA*, *F. Roemer*.

Fig. 5.—The specimen seen from above, showing the canal-apertures. Natural size. From Caradoc strata at Haverfordwest, South Wales. The original specimen in the Museum of the Geological Survey, Jernyn Street.

Fig. 5 a.—A transverse section of the same specimen, showing traces of the canals. The spicular structure is not preserved.







### PLATE III.

Figs. 1, 1 *a*, 1 *b*.—*PLECTODERMA SCITULUM*, *Hinde*.

Fig. 1.—A portion of the wall of the Sponge, showing the disposition of the spicular-mesh, for the most part represented merely by negative casts. Natural size. From Upper Ludlow strata in the Pentland Hills. The original specimen in the Collection of the Geological Survey of Scotland, Edinburgh.

Fig. 1 *a*.—A portion of the same specimen, showing the fasciculate arrangement of the vertical rays, and the single disposition of the transverse rays of the mesh-spicules. The silica of the spicules is, in part, preserved. Magnified five diameters.

Fig. 1 *b*.—Another portion of the specimen, similarly enlarged, showing casts of cruciform-spicules. In the larger spicule, to the right of the figure, a fifth ray is indicated.

Figs. 2, 2 *a*, 2 *b*.—*PHORMOSELLA OVATA*, *Hinde*, nov. sp.

Fig. 2.—Impressions of nine individuals on a slab of arenaceous rock. Natural size. From Ludlow strata at Mocktree, Shropshire. The original specimen in the Museum of the Geological Survey, Jermyn Street.

Fig. 2 *a*.—A single Sponge, magnified two diameters.

Fig. 2 *b*.—A portion of the surface of a specimen showing the disposition of the cruciform-spicules in the Sponge-wall. Enlarged five diameters.

Figs. 3, 3 *a*—*f*.—*AMPHISPONGIA OBLONGA*, *Salter*.

Fig. 3.—Casts of nine individuals, closely associated together on a slab of arenaceous rock. Natural size. From Upper Ludlow strata at Wetherlawlinn, Pentland Hills, near Edinburgh. The original specimen in the British Museum (Natural History).

Fig. 3 *a*.—A single Sponge with indications of an axial hollow in its lower portion. Natural size.

Fig. 3 *b*.—A portion of the upper surface of a specimen, showing the regular arrangement of the spicules, now represented by negative casts. Enlarged ten diameters.

Figs. 3 *c*, 3 *d*.—Casts of two detached spicules, forming the upper portion of the Sponge. Enlarged twenty diameters.

Figs. 3 *e*, 3 *f*.—Casts of two detached conical spicules, forming the basal portion of the Sponge. Enlarged ten diameters.









## PLATE IV.

### Fig. 1.—RECEPTACULITES NEPTUNI, *Defrance*.

A fragmentary specimen showing the inner or upper surface, in places worn down so that only transverse sections of the vertical rays of the spicules are exposed. Natural size. From Devonian strata at Mudstone Bay, Devonshire. The original specimen in the collection of A. Champenowne, Esq., F.G.S.

### Figs. 2, 2 a—2 d.—SPHÆROSONGIA TESSELLATA, *Phillips*, sp.

Fig. 2.—An imperfect specimen; showing very distinctly the hexagonal summit-plates of the spicules. Natural size. From Middle Devonian strata at Newton Bushell, Devonshire. The original specimen in the Museum of the Geological Survey, Jermyn Street.

Fig. 2 a.—A vase-shaped specimen, the upper portion concealed by the matrix. Natural size. The original specimen in the British Museum (Natural History).

Fig. 2 b.—An imperfect specimen, showing the inner surface of the Sponge-wall, and the vertical and concentric ridges formed by the transverse spicular rays. Natural size. The original specimen in the British Museum (Natural History).

Fig. 2 c.—A fragment of a specimen showing the spicular structure of the inner surface of the wall. Enlarged two diameters. The original specimen in the British Museum.

Fig. 2 d.—Another fragment showing the transverse rays of the individual spicules in connection with their respective summit-plates. Enlarged two diameters. The original specimen in the Museum of the Geological Survey, Jermyn Street.

This specimen, as well as those mentioned above, are from Middle Devonian strata, at Newton Bushell, Devonshire.

### Fig. 3.—GEODITES SIMPLEX, *Hinde*, sp. nov.

A group of detached, siliceous spicules of various sizes. Enlarged twenty diameters. From decayed chert in Carboniferous Limestone at Ben Bulbin, Sligo, Ireland. The original specimens in the collection of Joseph Wright, Esq., F.G.S., Belfast.

### Fig. 4.—RENIERA SCITULA, *Hinde*, sp. nov.

Detached cylindrical spicules. Enlarged twenty diameters. Also from Carboniferous Limestone at Ben Bulbin, Sligo.

### Figs. 5 a—5 f.—RENIERA CARTERI, *Hinde*.

Detached spicules, showing variations in size and form. Enlarged twenty diameters. From the Upper Limestone series of the Lower Carboniferous, at Dalry, Ayrshire. The original specimens in the collection of Dr. R. J. Hunter, Carlisle.

### Fig. 6.—AXINELLA VETUSTA, *Hinde*, sp. nov.

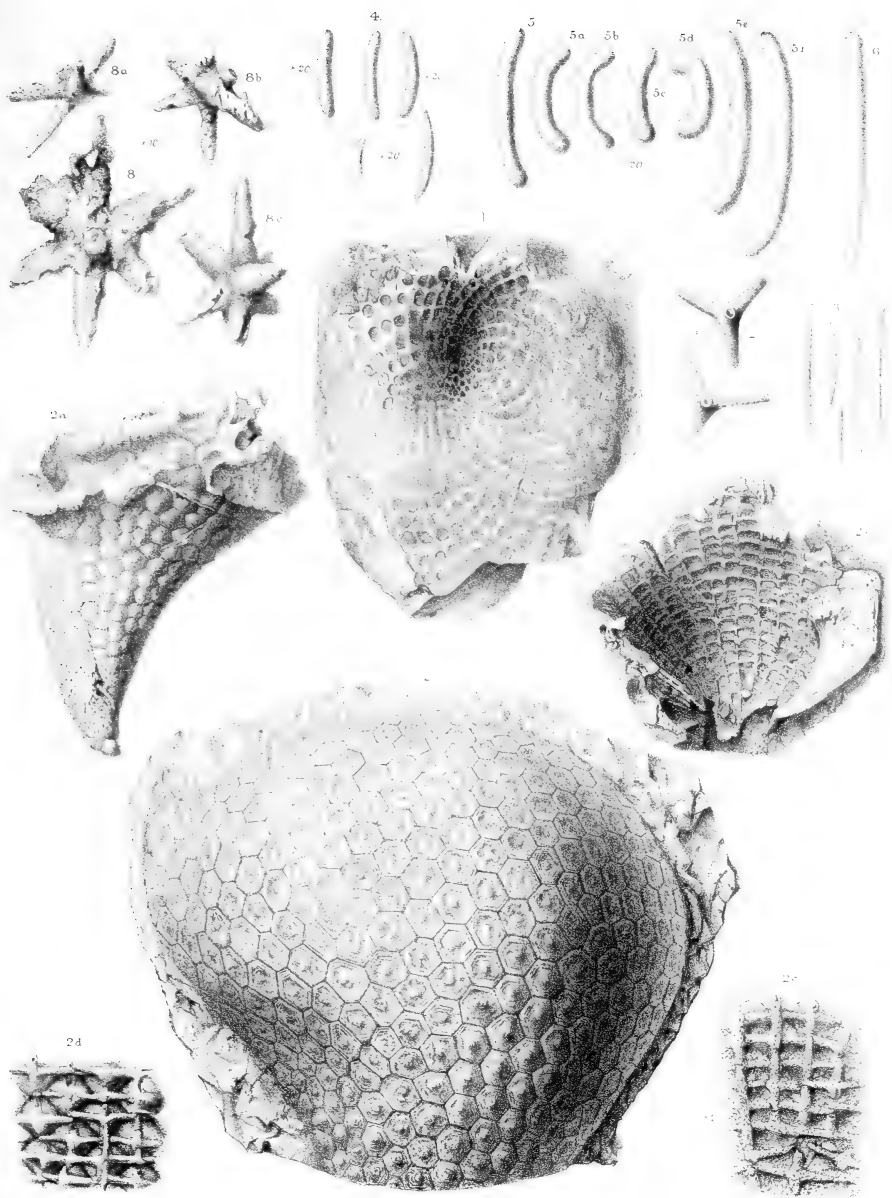
Detached acute spicule. Enlarged twenty diameters. From the same horizon and locality as the preceding species. The original specimen in the collection of Mr. John Smith, of Kilwinning.

### Fig. 7.—PACHASTRELLA HUMILIS, *Hinde*, sp. nov.

Detached four-rayed spicules. Enlarged forty diameters. From Carboniferous Limestone at Ben Bulbin, Sligo.

### Figs. 8, 8 a—8 c.—ASTRÆOSPONGIA DEVONIENSIS, *Hinde*, sp. nov.

Several detached spicules, the rays imperfect and partly encrusted by matrix. Enlarged ten diameters. From Middle Devonian strata at Newton Abbot, Devonshire. The original specimens in the collection of Mr. John Smith, Kilwinning.







## PLATE V.

Figs. 1, 1 *a*, 1 *b*.—*HAPLISTION ARMSTRONGI*, *Young and Young*.

Fig. 1.—The type-specimen, showing its upper surface. Enlarged two diameters. Lower Carboniferous. From the upper part of the Lower Limestone series at Cunningham Baidland, Ayrshire. The original specimen in the collection of Dr. R. J. Hunter, Carlisle.

Fig. 1 *a*.—A fragment of another specimen, showing the partially weathered-out spicules composing the fibres. Enlarged fifteen diameters. From Law Quarry, Dalry, Ayrshire.

Fig. 1 *b*.—A portion of the same, still further enlarged to forty diameters, showing the arrangement of the spicules.

Figs. 2, 2 *a*.—*HAPLISTION VERMICULATUM*, *Carter*, sp.

Fig. 2.—The type-specimen, showing the upper surface. Enlarged two diameters. Lower Carboniferous, upper part of the Lower Limestone series, at Cunningham Baidland, Ayrshire. The original specimen in the collection of Mr. James Thomson, F.G.S., Glasgow.

Fig. 2 *a*.—A portion of the same specimen, showing the conical extensions of the fibres and the partially weathered-out spicules. Enlarged twenty diameters.

Figs. 3, 3 *a*—3 *d*.—*GEODITES ANTIQVUS*, *Hinde*.

Fig. 3.—Detached acerate spicules referred to this species. Enlarged twenty diameters. Lower Carboniferous. Upper Limestone series, Glencart, Dalry.

Figs. 3 *a*—*d*.—Detached bifid and trifid spicules. The shafts of all are imperfect. Enlarged twenty diameters. From the same horizon and locality as the preceding. The original specimens in the collections of Mr. J. Smith and of Dr. R. J. Hunter.

Figs. 4, 4 *a*—4 *g*.—*GEODITES DEFORMIS*, *Hinde*, sp. nov.

Figs. 4, 4 *a*—4 *c*.—Detached fusiform and sub-cylindrical spicules referred to this species. Enlarged ten diameters. From the Lower Carboniferous, upper part of the Lower Limestone series at Law Quarry, Dalry.

Figs. 4 *d*—4 *g*.—Detached bifid and trifid spicules of this species. The shafts in all are imperfect. Enlarged ten diameters. From the same beds as the preceding. The original specimens in the collections of Mr. John Smith and Mr. James Bennie.

Figs. 5, 5 *a*—5 *c*.—*PACHASTRELLA VETUSTA*, *Hinde*.

Detached four- and five-rayed spicules, referred to this species. Enlarged twenty diameters. From Lower Carboniferous, upper part of Lower Limestone series, Law Quarry, Dalry. The original specimens in the British Museum (Natural History) and in the collection of Mr. J. Smith.

Figs. 6, 6 *a*—6 *f*.—*CNEMIDIATRUM PRISCUM*, *Hinde*, sp. nov.

Detached spicules of various forms, referred to this species. Enlarged forty diameters. From Carboniferous Limestone at Ben Bulbin, Sligo, Ireland. The original specimens in the collections of Mr. J. Wright and of Mr. H. J. Carter, F.R.S.

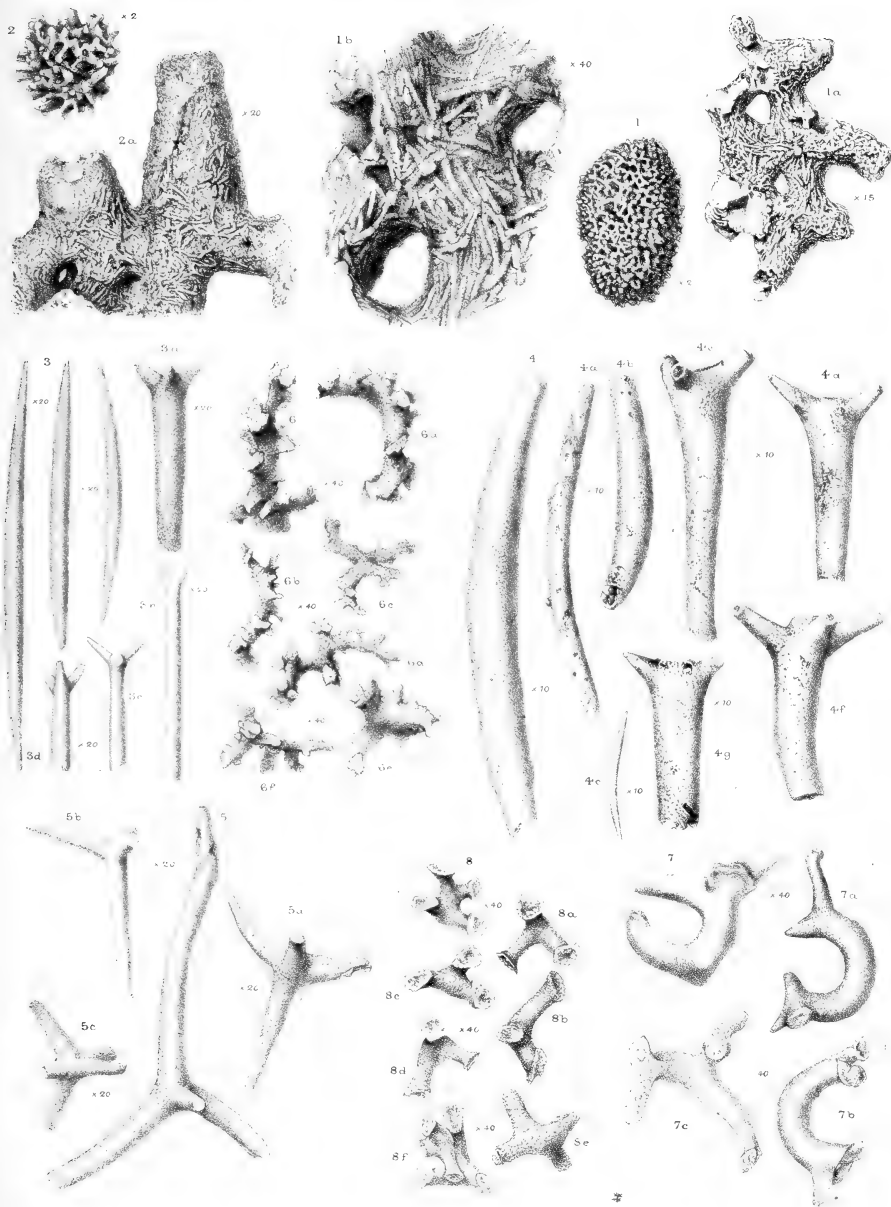
Figs. 7, 7 *a*—7 *c*.—*DORYDERMA DALRYENSE*, *Hinde*.

Detached spicules of various forms, referred to this species. Enlarged forty diameters. From the Lower Carboniferous, upper part of Lower Limestone series at Law Quarry, Dalry, Ayrshire. The original specimens in the British Museum and in the collection of Mr. J. Smith, Kilwinning.

Figs. 8, 8 *a*—8 *f*.—*HINDIA PUMILA*, *Hinde*, sp. nov.

Detached spicules of various forms, referred to this species. Enlarged forty diameters. From Carboniferous Limestone at Ben Bulbin, Sligo. The original specimens in the collection of Mr. Joseph Wright, F.G.S.









## PLATE VI.

Figs. 1, 1 *a*—1 *l*, 2, 2 *a*—2 *k*.—*HYALOSTELIA SMITHII*, *Young and Young*, sp.

Fig. 1.—A fragment of the dermal layer of the Sponge, showing the larger spicules in their natural position with respect to each other. Enlarged ten diameters. Lower Carboniferous, upper part of the Lower Limestone series at Cunningham Baidland, Dalry, Ayrshire. The original specimen in the collection of Mr. John Smith, Kilwinning.

Figs. 1 *a*—1 *l*.—Detached spicules of the skeleton and of the dermal layer. All enlarged to the same scale of ten diameters. 1 *a* represents a spicule of the dermal layer in which the sixth or distal ray is reduced to a small knob. In figs. 1 *f*, 1 *g*, five of the rays are similarly reduced. From the same locality and horizon, and in the same collection as the preceding.

Fig. 2.—A fragment of the anchoring-rope of the Sponge, composed of elongated spicular-rods. Partially embedded in a slab of limestone. Natural size. From Carboniferous Limestone (Yoredale series), near Richmond, Yorkshire. The original specimen in the British Museum (Natural History).

Fig. 2 *a*.—A transverse section of a portion of the same specimen, showing the spicular-rods in section. The clear circular spaces in the centre of each indicate the axial canals. Enlarged ten diameters.

Fig. 2 *b*.—A portion of a longitudinal section of the same specimen, showing three of the spicular-rods with the axial canal in the centre of each. The intervening dark bands consist of the calcareous matrix. Enlarged ten diameters.

Fig. 2 *c*.—A fragment of a detached spicular-rod, showing the central axial canal and parallel lines of growth. Enlarged ten diameters. From Law Quarry, Dalry. The original specimen in the collection of Mr. John Smith.

Figs. 2 *d*—2 *k*.—Detached fragments of the anchoring spicular-rods showing the four recurved rays at their distal extremities. All enlarged ten diameters. Lower Carboniferous at Low Baidland and Cunningham Baidland, Dalry, Ayrshire. The original specimens in the collection of Mr. J. Smith.

Figs. 3, 3 *a*—3 *g*.—*HYALOSTELIA PARALLELA*, *McCoy*, sp.

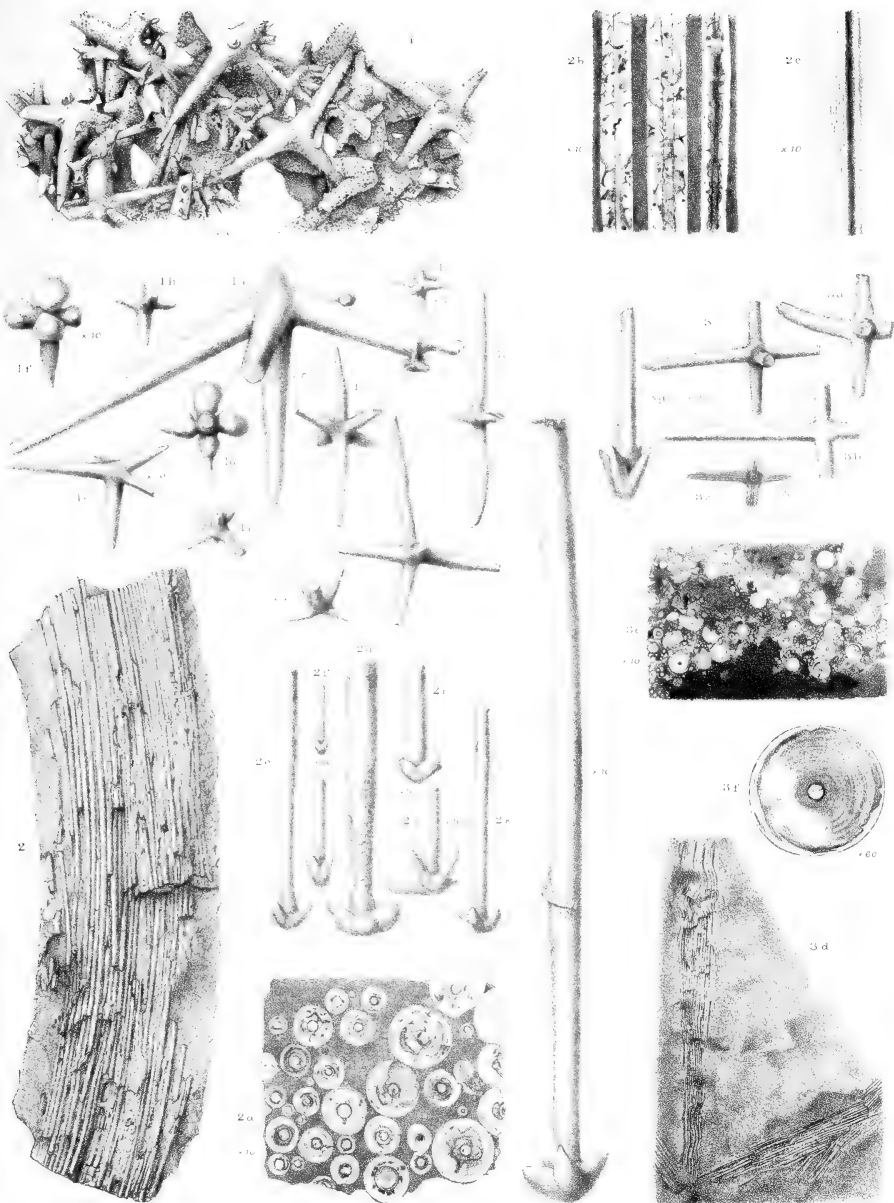
Figs. 3, 3 *a*—3 *c*.—Detached five-rayed spicules probably belonging to the dermal layer of the Sponge. Enlarged twenty diameters. From Carboniferous Limestone at Ben Bulbin, Sligo, Ireland. The original specimens in the collection of Mr. J. Wright.

Fig. 3 *d*.—Fragmentary bundles of spicular-rods forming the anchoring-rope of the Sponge. Exposed on the surface of a slab of dark limestone. Natural size. From Carboniferous Limestone, Clogher, Tyrone, Ireland. Drawn from part of the type specimen of *Serpula socialis*, Portl., now in the Museum of the Geological Survey, Jermyn Street.

Fig. 3 *e*.—A transverse section of one of the anchoring-ropes, showing great variation in the thickness of the component spicules. Enlarged ten diameters. From Carboniferous Limestone at Clitheroe, Lancashire. The original specimen in the British Museum.

Fig. 3 *f*.—Transverse section of one of the spicular-rods in 3 *e*, showing the central axial canal and concentric circles of growth. Magnified sixty diameters.

Fig. 3 *g*.—The distal extremity of one of the spicular-rods, showing the four recurved rays. Magnified twenty diameters. From Ben Bulbin, Sligo. The original specimen in the collection of Mr. J. Wright, Belfast.







## PLATE VII.

Figs. 1, 1 *a*—1 *g*.—*THOLIASTERELLA GRACILIS*, *Hinde*, sp. nov.

Figs. 1, 1 *a*, 1 *b*.—Fragments of the dermal layer of the Sponge, showing the inner surface, and the mode in which the horizontal rays of the spicules are interlaced, and partially fused together. The vertical rays of the spicules are directed towards the interior of the Sponge. Enlarged ten diameters. From the Lower Carboniferous, upper part of the Lower Limestone series at Law Quarry, Dalry, Ayrshire. The original specimens in the collection of Mr. John Smith, Kilwinning.

Figs. 1 *c*—1 *g*.—Detached spicules referred to the same species. In 1 *c*, 1 *d*, the inner or under surface of the spicule is shown, and in 1 *e*, 1 *f*, 1 *g*, the outer or upper surfaces; whilst in 1 *h*, the spicule, showing the vertical ray, is seen in profile. All enlarged ten diameters. From the same horizon and locality as the preceding.

Figs. 2, 2 *a*—2 *f*.—*THOLIASTERELLA YOUNGI*, *Hinde*.

Figs. 2, 2 *e*.—Fragments of the dermal layer of the Sponge, showing the inner or under surface and the interlacing of the spicules. Enlarged ten diameters. From the same horizon and locality as the preceding.

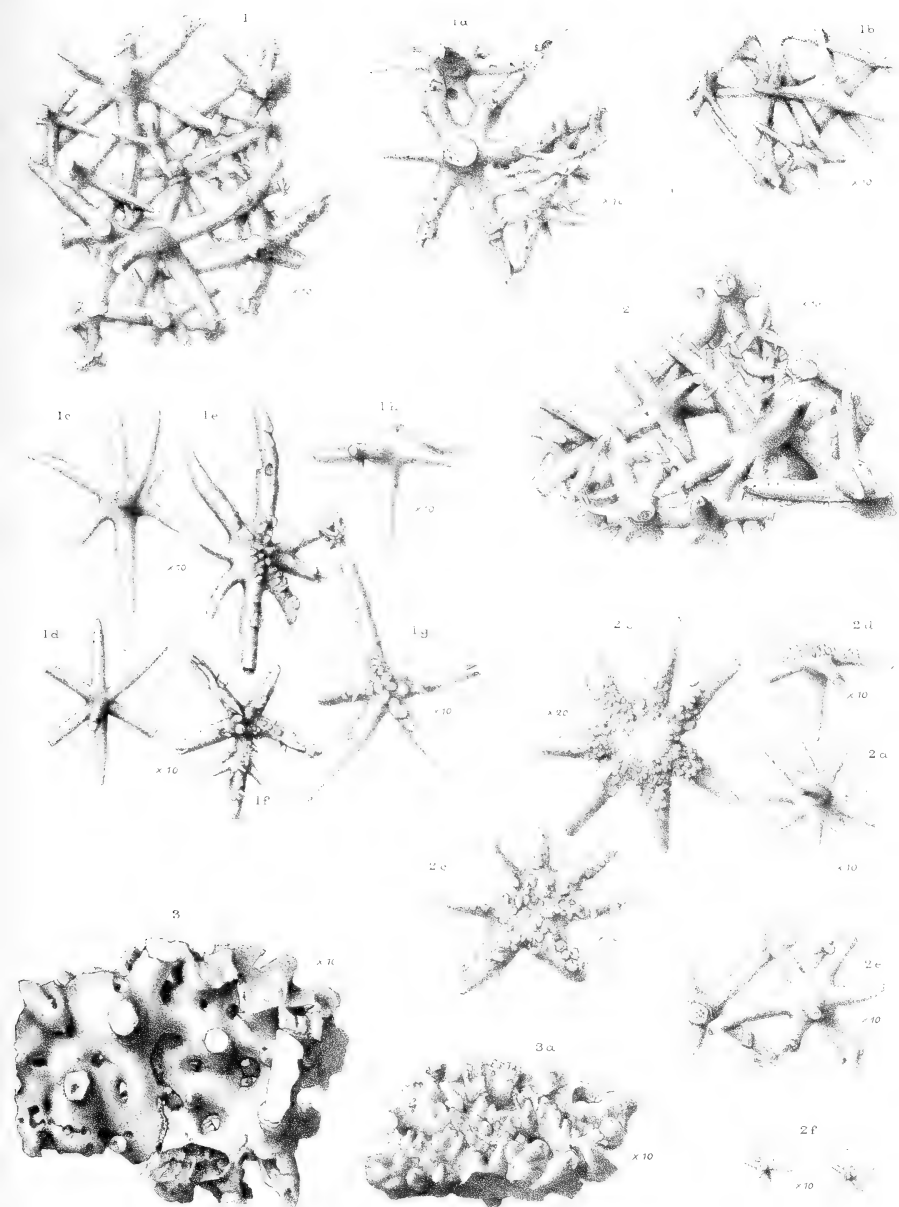
Figs. 2 *a*—2 *d*, 2 *f*.—Detached spicules referred to the same species. In 2 *a*, 2 *f*, the under surface of the spicules is shown; in 2 *b*, 2 *c*, the upper surface; whilst 2 *d* is seen in profile. The original specimens in the collection of Mr. John Smith.

Figs. 3, 3 *a*.—*THOLIASTERELLA COMPACTA*, *Hinde*, sp. nov.

Fragments of the dermal layer of the Sponge. Fig. 3 shows the inner surface, and the mode in which the spicular rays are completely fused together. The vertical or entering rays of the spicules are broken off, and only their truncated bases remain. Fig. 3 *a* shows the upper or outer surface of another fragment. Enlarged ten diameters. From the Lower Carboniferous at Law Quarry, Dalry, Ayrshire.

The original specimens in the collection of Mr. James Bennie.









## PLATE VIII.

Figs. 1, 1 *a*—1 *h*.—*SPIBACTINELLA WRIGHTII*, *Carter*, sp.

Fig. 1.—A large skeletal-spicule in which the distal ray and the four transverse rays are bifurcate.

Figs. 1 *a*, 1 *b*.—Smaller skeletal-spicules with simple rays.

Fig. 1 *c*.—A skeletal-spicule in which all the rays are furcate.

Figs. 1 *d*, 1 *e*.—Small six-rayed spicules in which each of the rays are divided at their extremities.

Figs. 1 *f*, 1 *g*, 1 *h*.—Stellate spicules resulting from the bifurcation of six-rayed spicules.

The specimens are all drawn to the same scale of forty diameters. From decayed chert in Carboniferous Limestone at Ben Bulbin, Sligo, Ireland. The original specimens in the collection of Mr. J. Wright, F.G.S., of Belfast, with the exception of 1 *d*, 1 *e*, which belong to Mr. H. J. Carter, F.R.S.

Figs. 2, 2 *a*—2 *g*.—*HOLASTERELLA CONFERTA*, *Carter*.

Figs. 2, 2 *a*—2 *d*.—Fragmentary six-rayed spicules of the skeleton, free or partially cemented together. 2 *a* is magnified forty diameters, and the others twenty diameters. From Lower Carboniferous, highest bed of the Upper Limestone series, near Dalry, Ayrshire. The original specimens in the collection of Mr. H. J. Carter, F.R.S.

Figs. 2 *e*, 2 *f*, 2 *g*.—Small stellate spicules. Magnified forty diameters. From the type-specimen in the collection of Mr. James Thomson, F.G.S.

Figs. 3, 3 *a*—3 *h*.—*ASTERACTINELLA EXPANSA*, *Hinde*.

Figs. 3, 3 *a*—3 *d*.—Various forms of skeletal-spicules. With the exception of 3 *e*, which is magnified twenty diameters, the spicules are enlarged ten diameters.

Fig. 3 *e*.—A corolla-like spicule, showing the upper surface. Magnified twenty diameters.

Fig. 3 *f*.—A similar spicule, showing the under surface. Magnified ten diameters.

Figs. 3 *g*, 3 *h*.—Small irregular stellate spicules. Magnified twenty diameters.

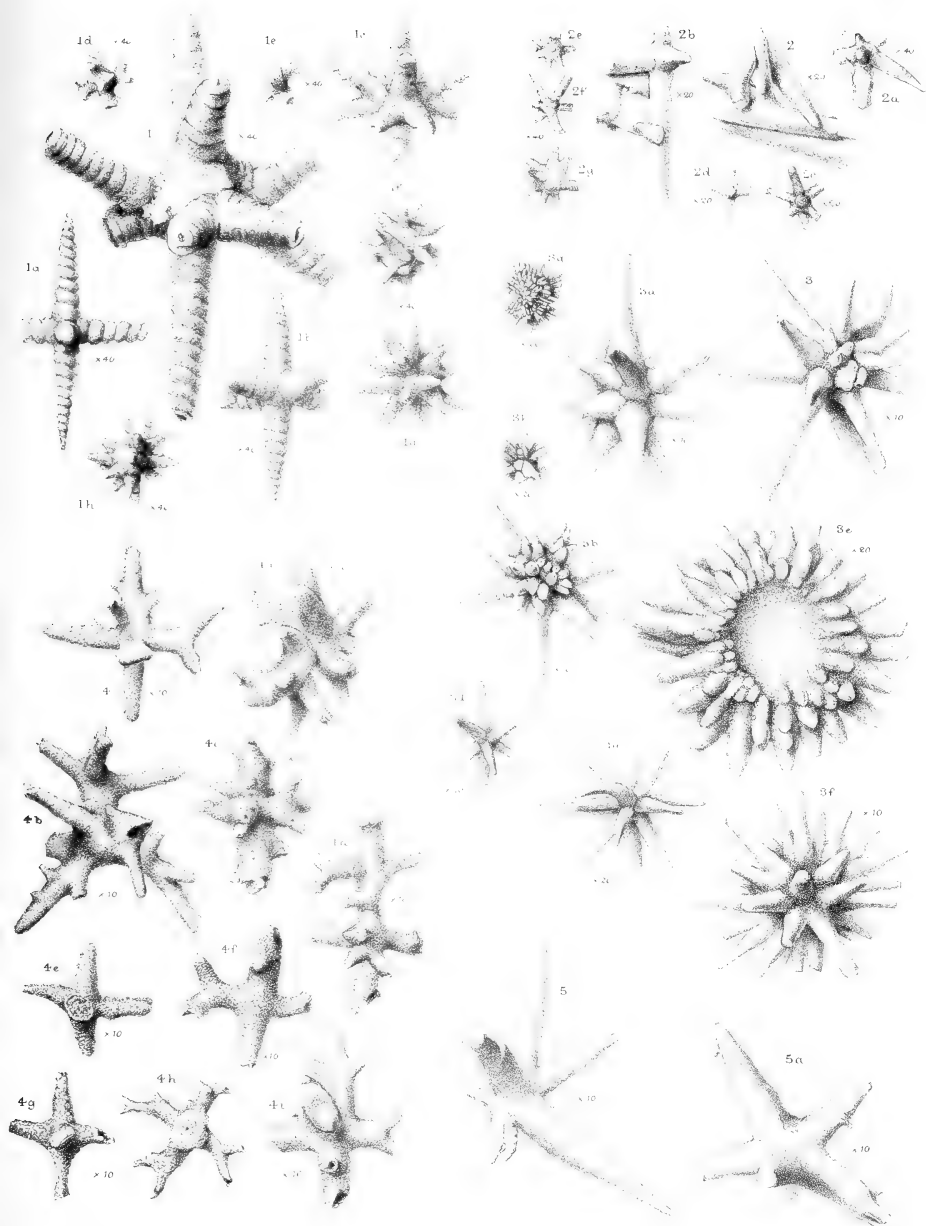
From the Lower Carboniferous, upper part of the Lower Limestone series, at Law Quarry, Dalry, Ayrshire. The original specimens in the collection of Mr. J. Smith, Kilwinning.

Figs. 4, 4 *a*—4 *i*.—*ACANTHACTINELLA BENNIEI*, *Hinde*.

Different forms of detached skeletal-spicules. Enlarged ten diameters. Lower Carboniferous, upper part of the Lower Limestone series, at Law Quarry, and Cunningham Baidland, Dalry, Ayrshire. The original specimens in the collections of Mr. J. Smith, Mr. J. Young, F.G.S., and Mr. J. Bennie.

Figs. 5, 5 *a*.—*THOLASTERELLA CRASSA*, *Hinde*, sp. nov.

Two detached skeletal-spicules. Enlarged ten diameters. Lower Carboniferous, lower part of the Lower Limestone series, Crawford Quarry, Beith. The original specimens in the collection of Mr. J. Young, F.G.S.











THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCLVII.

VOLUME FOR 1886.

L O N D O N

MDCCCLXXXVII.



A MONOGRAPH

OF THE

BRITISH JURASSIC GASTEROPODA.

BY

WILFRID H. HUDLESTON, M.A., F.R.S., SEC.G.S.

GENERAL INTRODUCTION.

PAGES 1—15.

AND

PART I, No. 1.

GASTEROPODA OF THE INFERIOR OOLITE.

PAGES 17—56.

LONDON :

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1887.

PRINTED BY  
ADLARD AND SON, BARTHOLOMEW CLOSE.

# MONOGRAPH

OF THE

## BRITISH JURASSIC GASTEROPODA.

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### GENERAL INTRODUCTION.

SINCE the publication of the SUPPLEMENT to the GREAT-OOLITE MOLLUSCA in 1863 no attempt has been made to deal with any portion of the Jurassic Gasteropoda in the works of the Palæontographical Society. It is true that the "British [Jurassic] Belemnites" formed the subject of a Monograph by the late Professor Phillips, whilst the Lias Ammonites have had ample justice done to them quite recently by the late Dr. Wright, and the Jurassic (as well as Cretaceous) *Trigonia* by the late Dr. Lycett. But the Mesozoic Gasteropoda have been singularly neglected, so that, in point of fact, there has been no Monograph dealing either with them or with the Pelecypoda "as a whole" since Lycett's last work, published four and twenty years; and to this long lapse of time we must add nine years since the date of the latest issues of the GREAT-OOLITE MOLLUSCA. One might almost imagine that this admirable Monograph, in conjunction with the no less valuable Supplement, had exhausted the subject of the Mollusca of the Lower Oolites, although professing to deal with the upper or Bathonian<sup>1</sup> division only.

Each age has its own speciality and its own way of looking at things. Thus the middle of the nineteenth century witnessed the appearance of the standard works of Deslongchamps, Goldfuss, D'Orbigny, Morris and Lycett, and many others. Those were the days when the discovery and naming of fossil Mollusca formed an exceedingly popular branch of science. But for some time past our biologists and palæontologists have been engaged in the more difficult task of working out the structure and affinities of the lower and obscurer classes. Thus, for nearly a quarter of a century, whilst the Sponges, Corals, Foraminifera, and

<sup>1</sup> It will be remembered that a few of the Gasteropoda figured in this work, such as "*Pterocera*" *Bentleyi*, and the shells in Plate XV (from Yorkshire), belong to the Bajocian or Inferior Oolite division of the Lower Oolites.

other Microzoa generally have received a large share of attention, the Mollusca seem to have been comparatively neglected. On the other hand, the Vertebrata have always had a number of eminent exponents, whose work has rendered the publications of the Palæontographical Society of peculiar value and interest.

On the whole, the great age of molluscan palæontology, as evinced by such works as those already quoted, preceded the announcement in England of the doctrine of Evolution by about ten years. It is true that this doctrine, now so universally accepted, had been most ably pre-figured by Lamarck and others; yet it had met with little favour from biologists or palæontologists previous to the appearance of Darwin's great book. Hence the age of Goldfuss, of D'Orbigny, and of Morris and Lycett, was an age when the general faith in distinct creations was at its height. This is what Professor Marsh calls the third period in palæontology,<sup>1</sup> when a species was regarded as a rigid entity, and he who "made" or described a species acquired a sort of prescriptive right therein. "So long as the bulk of naturalists really believed in the immutability of species there was something dangerously fascinating in the prospect of finding out and describing a *form-group*, which was destined to endure no change, which might indeed be destroyed or die out but could never be altered. The maker of a new species would thus come to look upon his offspring with almost parental solicitude, and having stood godfather to his own child would attach to the name given by him a peculiar interest."<sup>2</sup>

Perhaps the belief of that day was on the whole favourable to accurate definition, and there is no doubt that the practice adopted by some collectors of burking doubtful forms and varieties rendered it more easy to constitute and define "species." It must, however, be allowed that, when once the doctrine of Evolution is admitted in its entirety, the ideas attaching to such expressions as "genus" and "species" lose somewhat of their definition. Nevertheless they are necessities in classification; and even if they do not absolutely exist in nature, it becomes necessary as by a sort of legal fiction to presume that they do exist for purposes of scientific arrangement. But the palæontologist has to deal with the element of time in addition to his other difficulties, and thus for him, far more than for the malacologist, does it become necessary not to place too rigid a meaning on "genus" and "species."

I fear that this will appear somewhat heretical even in these days of belief in Evolution; but, as very justly observed by Professor Cope, the fact that all definitions which separate adjacent groups will be ultimately found to be fallible does not permit us to fall "into inexact and inconsistent methods of definition." Hence the work of definition need not be slovenly because we no longer believe

<sup>1</sup> "Address before the American Association for the Advancement of Science, 1879."

<sup>2</sup> W. H. Hudleston on the Yorkshire Oolites, 'Proc. Geol. Assoc.,' vol. v, p. 460.

it to be final. Nay, the more exact it is the easier will it be to trace the links which lead up to another group of forms.

At the same time the malacologist must not be hard on the fossil-conchologist because the latter cannot turn out such exact work as the stricter requirements of modern biology seem to demand. The malacologist has a wide grasp of space, but it is all on one plane as it were; there is no depth in it. The work lies on the surface and relates wholly to the present, whereas the work of the palæontologist lies in a series of perpetually receding planes, and bears the same relation, metaphorically speaking, to the study of existing life that solid geometry does to superficial. Of course it is admitted that palæontology, or rather that branch of it which may be called mineral conchology, is to a certain extent empirical in its methods, and these guesses at truth are not perhaps always of the happiest kind; still, it is more than probable that in the past there has not always been such sharp divisions as are required by the logical definition of "genus" and "species"; whilst the still more artificial "family" would be more difficult to outline the farther we go back in time.

#### DIVISIONS OF THE SUBJECT.

The Gasteropoda are usually regarded as dwellers in shallow water, and hence any notable accumulation of this class of shells would be looked upon as indicative of seas of moderate depth at the time that such accumulations were made. In the Jurassic rocks of England their distribution is very unequal; considerable thicknesses of rock are found to be almost devoid of Gasteropoda, and then again a few feet of beds may contain large quantities of them. They are, in fact, less sporadically distributed than the Brachiopoda or the Pelecypoda, and, on the whole, very much more difficult to procure in good condition. From their uncertain and unequal distribution, and also from the fact that Gasteropoda have been greatly influenced by the physical conditions that obtained during the period of deposition, it is probable that they are of less value as indicators of horizons than the Cephalopoda, the Ammonites especially. Moreover, with the exception of one or two groups, such as *Nerinea*, their mutations have been much less rapid, so that forms have been more enduring, and thus sundry demoid types may be said to pervade nearly all the beds.

In dealing with our Jurassic Gasteropoda two alternative plans present themselves: (1) To carry each genus through from the lowest to the highest beds—the biological plan adopted both by Goldfuss and d'Orbigny; or, (2) to adopt the stratigraphical plan, and to take no more than a series of beds for complete description. The first method is the more philosophical of the two, but also the

one which involves the most trouble and preparation. The second method, besides being the most feasible, has, moreover, been already inaugurated by Morris and Lycett in their description of the Great-Oolite Mollusca. Hence there exists, as it were, a sort of prescription to describe the fossils according to their horizons, and it therefore only remains to determine what divisions shall be adopted. On the whole I am inclined to think that it would be the most advisable to complete the description of the Gasteropoda of the LOWER OOLITES, already so well begun. For this reason the *Gasteropoda of the Inferior Oolite* have been chosen to constitute the *first memoir* of the contemplated Monograph.

It does not appear that many important additions have been made to the Gasteropod Fauna of Bathonian beds in England since the date of Lycett's 'Supplement.' Hence with the completion of the proposed 'Memoir on the Gasteropoda of the Inferior Oolite,' the Gasteropod Fauna of the Lower Oolites will, in the main, have been exhausted. It would then become a question as to what should be the subject of the next memoir.

If the Middle and Upper Oolites, from the Kelloway Rock to the Portland-Purbeck inclusive, were made the subject of a second memoir, complete as regards the Gasteropoda, considerable advantages in the way of comparison would ensue. This course is the more to be recommended, since there is a disposition to regard the so-called Middle and Upper Oolites together as one great series of the Jurassic system. Nevertheless the difficulties which present themselves in having to grasp such a wide extent of beds are considerable; for the number of collections that have to be searched must be borne in mind, and how differently as regards synonymy the fossils are arranged in each. Nothing, it is true, can exceed the readiness with which the chief authorities of our public museums render all the facilities in their power; but in some cases the rules do not admit of more than an inspection, whereas everyone who has had any experience knows what an advantage it is to possess a fossil, even for a few weeks—to study it and to be thus enabled to determine its characters under various conditions of light. Hence the importance of making use of private collections.

The Gasteropoda of the Liassic Rocks might possibly form the subject of a third memoir, and in this connection it would be a subject of considerable interest to ascertain how far the Gasteropoda of the Lias, and especially of the Upper Lias, resemble those of the Inferior Oolite. My belief is that they would be found to do so to a much greater extent than is generally supposed, though the Gasteropod Fauna of the Inferior Oolite in our country is much fuller than that of the Lias; many of the genera which attain to such an important position in the Inferior Oolite are prefigured in the Lias. These remarks more especially apply to the south-west of England.

People who derive their impressions of the Faunas of two series of beds from



studying lists of fossils merely, can have very little idea of their true biological relations. This is owing to several causes, not the least of which is the unequal value of specific distinctions. This being so, it follows that under the present system of nomenclature comparisons by the percentage method are not of the highest order of merit; but such comparisons are still further weakened by mistakes in synonymy, which not seldom serve to aggravate the erroneous impressions as to alleged differences in two series under consideration. What shall we say, for instance, to a large and important group of fossils, characteristic alike of the Inferior Oolite and the Lias, being referred in one case to the genus *Amberleya*, and in the other case to the genus *Eucyclus*? Nay, more, in the very collection where this arrangement has been adopted, the genus *Amberleya* is placed under the Turbinidæ, whilst the genus *Eucyclus* is placed under the Littorinidæ. Yet the merest tyro in Jurassic palæontology knows that *Eucyclus* is a name given by Deslongchamps to a group of shells characterised, but not fully diagnosed, by Morris and Lycett nearly ten years before under the name of *Amberleya*. Whichever name we adopt the genus is the same; to call it by the first name in the Lias, and by the second name in the Inferior Oolite, is one way of making an artificial gap in the geological record. Doubtless comparative lists of fossils contained many such artificial gaps.

## NOMENCLATURE.

Like rates and taxes, Nomenclature is a necessary evil, but out of nomenclature has grown that fearful incubus, Synonymy, which threatens at some time to overwhelm us unless the Augean stable be cleansed. It is not intended in this Monograph to attempt anything more than a kind of selective synonymy in respect to the species described. No single individual nowadays can pretend thoroughly to cope with synonymy. Nothing short of an international commission of experts can ever do this, and we may well believe that matters are hardly ripe for such a consummation at present. The dread of having to deal with this horrible nightmare makes people rather shy of undertaking molluscan palæontology, which may be said to suffer from this disease more than any other branch of the tree of life.

But genuine nomenclature itself, even when free from its terrible parasite, is a subject full of difficulties. We are often and justly reminded that nomenclature is not science, and in fact many of our more philosophic biologists are rather hard upon nomenclature, because, as with liberty, much evil is done under its cover. Returning, however, to our original position that it is a necessary evil, we must endeavour to deal with it in a manner which we may hope will yield the most satisfactory results. Shall we continue to put new wine into old bottles? is the

essence of a question which has been frequently asked of late years. Those who ask such a question contend that, since the practical acceptance of the doctrine of Evolution by the scientific world, the old binomial system is insufficient for the requirements of biological knowledge.

It will be remembered that an important congress of naturalists was held some time ago at the British Museum under the presidency of Professor Flower, for the purpose of discussing the subject of zoological nomenclature. All parties were well represented—uncompromising binomialists, limited trinomialists, and thorough trinomialists. As far as the philosophy of the subject in dispute went, it appeared to me that the trinomialists had the best of it; but when it came to a matter of policy and practice, the more conservative side had much to say in favour of the old method. In summing up, Professor Flower, who declared himself a limited trinomialist, said that distinctly defined species undoubtedly exist in great numbers owing to the extinction of intermediate forms; for such the binomial system offers all that is needed in defining them. But infinite gradations are being traced, both of present and especially of past forms; in order to deal with these even a trinomial system would in many cases be inadequate. He considered that sooner or later far more radical changes would have to be introduced.

These remarks refer more especially to the higher classes of creatures, but they serve to show the danger of departing from the old course at present. It is not, therefore, because I consider the binomial system the most philosophic or the best, but because I consider it the least calculated to mislead under the circumstances that it has been adopted for this Monograph. We must jog on as well as we can with the help of sub-genera and var. *a* and var. *b*, and this no doubt can be done without any difficulty. Moreover, in the case of fossil mollusca, we must never lose sight of the fact that, biologically, we are walking somewhat in the dark, and also that mineralisation, by the changes it sometimes superinduces, adds to our uncertainty in these matters. Hence the fossil-conchologist, treading on somewhat doubtful ground, should not be over anxious to emphasise differences the precise value and meaning of which are not so very obvious in all cases. When we have to deal with a demoid group, such as some of the small *Cerithia* for example, the larger the collection and the fewer the specific names we should be disposed to give, whereas the varietal names would be numerous. It is, in fact, these demoid forms with their numerous links which most require the assistance of a third name. Of course these remarks have reference to the Jurassic Gastropoda only. The Cephalopoda might perhaps require somewhat different treatment; in fact, the difficulty as regards the Ammonites is practically got over by splitting the genus, and even that method is hardly enough for such a sporting group.

## CLASSIFICATION.

If it be true that too many cooks spoil the broth, the same may be said of the numerous systems of classification which have been put forward for the Mollusca. A friend of mine, who has a large collection under his charge, despairing of ever arriving at the right method, once said in the bitterness of his heart that he was thinking of adopting an alphabetical classification based upon genera. As one would fain believe that the main object of classification is arrangement according to affinities real or supposed, it is evident that such an act, if adopted for a collection and not for a catalogue, would be a piece of zoological suicide. It certainly may be argued with irresistible logic that, since the systems of classification are so numerous, they cannot all be right, and that the chances are against any one that may be selected.

But, after all, a collector would hardly like to store his fossils on principles which might very well commend themselves to a dealer; and rightly or wrongly it is his duty to attempt some system of classification which shall be an aid to comparison as well as to differentiation. Then arises the question, for us more especially important, what is the best basis for a classification of the Gasteropoda? To many malacologists lingual dentition commends itself as the means whereby the most philosophic system of classification may be effected, whilst others incline to attach more weight to the shell itself. Hence, S. P. Woodward, in the 'Manual of the Mollusca,' divided the Prosobranchiata, with which we are mostly concerned, into Siphonostomata and Holostomata, the former including the bulk of the carnivorous Gasteropods—always excepting *Natica*. But the exception of this large and ancient genus is an awkward one, and it proves that the divisions adopted do not coincide with the divisions based on the modes of nutrition. There is also another difficulty in connection with the arrangement of the 'Manual of the Mollusca,' viz. placing *Cerithium* and *Aporrhais* amongst the Holostomata. It matters nothing whether these are vegetable feeders or not; clearly their shells are not holostomatous in the strict sense of the term, although on other grounds the affinities of the animal may be more with the Holostomes than with the Siphonostomes. This subject has been well discussed in the 'Palæontologica Indica' by Stoliczka, who arrived at the conclusion that such divisions as Siphonostomata and Holostomata might be accepted provisionally, but without giving such divisions any prominence.

Any system based mainly on lingual dentition cannot exactly commend itself to a palæontologist. The palæontology of the Gasteropoda is sufficiently empirical without importing this fresh element of uncertainty. Who can say what was the lingual dentition of *Nerinaea*? Hence, whilst admitting to the full the value of

this method as applied to existing creatures, we must fall back upon the shell as the basis of classification for our fossils, and accept such aid from zoology as is consistent with the material at our disposal.

It would seem as though the interest in the study of the Mollusca had been reviving lately. This may be inferred from the fact of the publication of three useful and important manuals since the beginning of 1880. I allude (1) to the fourth edition of Woodward's 'Manual,' with appendix by Prof. Ralph Tate; (2) to the work on 'Structural and Systematic Conchology,' by George W. Tryon, junr., published at Philadelphia; and (3) to the 'Manuel de Conchyliologie,' by Dr. Paul Fischer, of which the portion completing the Gasteropoda appeared in February, 1886. This work is being published in Paris. These authors, as also Stoliczka in the 'Palæontologica Indica,' bear testimony to the invaluable character of the original Manual by S. P. Woodward, which is indeed, both as regards text and illustrations, a work of the very highest character, published at a price which places it within the reach of all.

With some important exceptions I hope to follow in the main the classification of the 'Manual of the Mollusca.' The most important exceptions are (1) in the position assigned to the Aporrhaidæ and Cerithiidae; (2) in adopting the family of the Pseudomelaniidae, to include the quondam Chemnitzias and possibly some of the Phasianellas of the Jurassic Rocks. It should be noted that S. P. Woodward always regarded the application of the term *Chemnitzia* to the great *Melania*-like shells of the Jurassic Rocks as provisional, and many palæontologists besides that author have felt dissatisfied with the arrangement. Still, I should scarcely have ventured on such an innovation without the sanction of Dr. Paul Fischer, whose high authority I must quote in justification. I have long wished to do this, and now in such good company have no further hesitation.

There are certain genera, moreover, in the Jurassic Rocks whose position seems very doubtful. Most of those to which I allude are more or less characteristic of beds of that age. A few may be mentioned here, though each genus will of course be fully dealt with in the descriptive part of the text. Any observations now made must be regarded as preliminary and incomplete.

The first of these is *Purpurina*, a genus founded but abandoned by d'Orbigny, who makes no mention of it in the text of the 'Terrains Jurassiques.' From the name given we may judge that the author would have placed his genus in the same family as *Purpura*. The genus *Purpurina* were practically reconstituted by Piette and Deslongchamps, who regarded it as having relations on the one side with *Turbo*, and on the other with *Cerithium* and *Purpura*. If these views be correct its family relations are by no means clear, and this circumstance may account for the contradictory position assigned to it by the various authorities. Thus Tryon places *Purpurina*, with a query, under the sub-family Purpurinæ, and also under

“Cancellariidæ,” in this way providing his bow with two strings. Tate, in the appendix to Woodward’s ‘Manual,’ places it in the “Cancellariidæ;” Stoliczka, in the ‘Palæontologia Indica,’ places it with a query in the Trichotropidæ; whilst Fischer actually places *Purpurina* amongst the Littorinidæ. The latter author assigns no reason for his conclusion, merely observing that Stoliczka’s approximation of the genus to *Trichotropis* appears to him a very doubtful determination. This subject has never been attentively studied by English palæontologists, partly owing to some of them having confounded *Purpurina* with Lycett’s genus *Purpuroidea*, and partly perhaps from the difficulty hitherto experienced in obtaining good specimens from our English beds.

The results are that an extremely well-marked group, judging, of course, from the shell alone, has been regarded as having affinities with *Purpura*, with *Cancellaria*, with *Trichotropis*, with *Cerithium*, with *Littorina*, and with *Turbo*. In fact, in this short-lived genus *Purpurina* authors have noted features characteristic at once of the Siphonostomata and of the Holostomata, of the Tectibranchiata and of the Scutibranchiata, of the Toxoglossæ, Rhachiglossæ, Tænioglossæ, and Rhipidoglossæ.

From this very remarkable case we may draw the inference that probably it is not easy to lay down the law as to family affinities in respect of Mesozoic fossils, and for this reason we should deprecate the criticisms of certain zoological martinets, who are only too ready to find fault with the palæontologist. There is also a second lesson to be learnt, viz. that in all probability there was a greater blending of common elements in the Mollusca of the remoter past than there is at the present time, and that consequently the rules of classification applicable to existing creatures must not be too rigidly enforced. In fact we must use our system with a view to the circumstances of the case and not allow it to tyrannise over us.

But then comes the question, which must be faced by any one who has undertaken to deal with the Jurassic Gasteropoda, where are we going to place *Purpurina* in the forthcoming Memoir on the Gasteropoda of the Inferior Oolite, seeing that it occupies such an important position in that series? Although I have my doubts about its being a true Siphonostome any more than *Amberleya*, yet bearing in mind the idea of the original founder of the genus, and, moreover, justified by the authority of Prof. Tate, I have concluded to place this genus at the head of the list, though leaving the question of family in abeyance.

Another still more important genus, eminently characteristic of the Inferior Oolite, is *Amberleya*. The authors of the ‘Great Oolite Mollusca,’ when they placed *Amberleya nodosa* under the Littorinidæ and *Amberleya (Turbo) capitanea* amongst the Turbinidæ, gave unconscious expression to a doubt, never yet cleared up, as to which of these two great families the new Jurassic genus should be referred. Subsequently both Deslongchamps and Lycett had no doubt that *Amberleya*

(*Eucyclus*, Desl.) should be placed amongst the Littorinidæ, and it is in that family that most systematists have placed the genus. Nevertheless, Terquem and Jourdy, Zittel, and Fischer are opposed to this view, and replace *Amberleya* in its old position amongst the Turbos. The latter author observes, "The various forms grouped under the generic name *Amberleya* have the appearance of *Tectaria*, of *Echinella*, and of *Littorina*, but the existence of a nacreous layer, ascertained to exist in the Jurassic Amberleyas, has shown their affinity with the Turbinidæ and the Trochidæ." I am not aware that any traces of a nacreous layer have been found in our British Amberleyas, but such is stated to be the case in the Jurassic of Moscow (Fischer quoting Zittel). Whilst quite prepared to admit that neither the diagnosis of Lycett nor of Deslongchamps is quite satisfactory, I am at present content to follow Prof. Tate in retaining *Amberleya* amongst the Littorines, the more so as this classification has the sanction of Stoliczka. At the same time I must repeat my belief, already expressed with regard to *Purpurina*, that some of these old genera probably possessed characters which are now rarely, if ever, combined in the same group at the present day. Hence the impossibility of a classification which will satisfy everybody. In the meantime, should any more decided proofs of the existence of a nacreous layer in these very handsome shells become available, it is not too late to alter the position of the genus.

In some respects there are characters of resemblance between the Purpurines and the Amberleyas, which may be more nearly related than has hitherto been supposed. As I wish to act as far as possible on the principle of precedent no change should be made for which I cannot quote a good authority in justification. But it has occurred to me that d'Orbigny may not have been so far wrong in placing these shells amongst the Turbos, and that possibly they might be made to constitute a sub-family of the Turbinidæ.

But such changes are not to be lightly made, and I should, moreover, always desire to uphold the decision of Morris and Lycett in the majority of doubtful cases. It is satisfactory to believe that, on the whole, their genera find favour with systematists such as Tryon in America and Fischer in France, although not seldom the family position of these has been changed. Morris and Lycett represented an age in the history of molluscan palæontology, when numerous forms hitherto unknown had to be located as best might be under the exigencies of the case. In conjunction with their illustrious contemporaries on the Continent of Europe they succeeded in defining most of the generic groups required for the Lower Oolites, and it is a satisfaction to think that if it should be necessary to split up an inconveniently large genus into sub-genera or sections, for the Lower Oolites at any rate, few if any additional genera are likely to be required.

The following Table shows the systematic position of certain genera of the

Prosobranchiata according to (1) FISCHER ('Manuel de Conchyliologie, &c.,' par le Dr. Paul Fischer, Paris. Gasteropoda concluded February, 1886). (2) TRYON ('Structural and Systematic Conchology,' by George W. Tryon, junr., Philadelphia, 1882-4). (3) TATE (Woodward's 'Manual of the Mollusca,' 4th edition, with appendix by Ralph Tate, A.L.S., F.G.S., London, 1880). (4) STOLICZKA ('Palæontologia Indica,' "Cretaceous Gasteropoda," by Ferd. Stoliczka, Ph.D., F.G.S., Calcutta, 1868); and (5) MORRIS AND LYCETT (Palæontographical Society, 'Monograph of the Great-Oolite Mollusca,' by J. Morris, F.G.S., and John Lycett, London, 1850-4).

LIST OF SOME GENERA OF GASTEROPODS, CHIEFLY JURASSIC,  
Provisionally arranged in alphabetical order. Family position according to five separate authorities, viz. *Fischer*, *Tryon*,  
*Tate* in Woodward's Manual, *Stoliczka*, *Morris* and *Lycett*.

	<i>Fischer.</i>	<i>Tryon.</i>	<i>Tate.</i>	<i>Stoliczka.</i>	<i>Morris and Lycett.</i>
1. Alaria .....	Alaria, <i>M. and L.</i> , 1854 [= Aporhaidæ], Chenuopodidae	<i>M. and L.</i> , Strombidae	<i>M. and L.</i> , 1854, Aporhaidæ after Cerithiidae	<i>M. and L.</i> , 1854, Alaria, comprising Strombidae and Aporhaidæ	Strombidae.
2. Amberleya .....	Amberleya, <i>M. and L.</i> , 1854, Turbinidae	Eucylus, <i>Desl.</i> , Littorinidae	—	Amberleya, <i>M. and L.</i> , Sub-fam. Littorininae	Pagodus, <i>Groy</i> , Sub-genus Amberleya, Littorinidae.
3. Bourguetia .....	Bourguetia, <i>Desl.</i> , 1871, Pseudomelanidae	<i>Desl.</i> , Eulimidae	—	—	—
4. Brachytrema .....	Brachytrema, <i>M. and L.</i> , 1850, ? Cerithiidae	<i>M. and L.</i> , Littorinidae or Cerithiidae	<i>M. and L.</i> , Cerithiidae, provisionally Calyptraeidae	<i>M. and L.</i> , Cerithiidae	Maricidae.
5. Capulus = Pileopsis .....	Capulus, <i>Mont.</i> , Capulidae	<i>Mont.</i> , Calyptraeidae	—	Capulidae	—
6. Cerithium .....	Cerithium, <i>Adam</i> , 1757, Cerithiidae. Between Struthio-laridae and Modulidae	<i>Brug.</i> , Cerithiidae, between Littorinidae and Melanidae	—	—	—
7. Ceritella .....	Ceritella, <i>M. and L.</i> , Cerithiidae	<i>M. and L.</i> , 1850, Cerithiidae	<i>M. and L.</i> , Cerithiidae, provisionally Pyramidellidae	<i>M. and L.</i> , Cerithiidae	—
8. Chemnitzia (fossil only) .....	Pseudomelanis, <i>P. and C.</i> , 1852, Pseudomelanidae	<i>D'Orb.</i> , Eulimidae	—	—	—
9. Chrysostoma .....	Chrysostoma, <i>Swain</i> , Trochidae	<i>Swain</i> , Trochidae	—	—	—
10. Cloughtonia .....	—	<i>Hadl.</i> , Naticidae	—	—	—
11. Cirrus .....	Cirrus, <i>J. Sowerby</i> , 1816, Dol-phinulidae	—	<i>Sow.</i> , Solaridae	—	—
12. Crossestoma .....	Crossestoma, <i>M. and L.</i> , Dol-phinulidae	<i>M. and L.</i> , Rotalidae	Turbinidae, see Dolphinula	—	—
13. Cryptania .....	Cryptania, <i>Eug. Desl.</i> , 1865, section of Pleurotomaria, Pleurotomaridae.	—	<i>Eug. Desl.</i> , Halotidae, Sub-fam. Scissurellinae	—	—
14. Cryptoplocus .....	Cryptoplocus, <i>P. and C.</i> , 1854, Sub-genus of Nerina, Neritidae	<i>P. and C.</i> , Pyramidellidae	<i>P. and C.</i> , Cerithiidae	—	—
15. Delphinula .....	Delphinula, <i>Lam.</i> , 1803, Dol-phinulidae	<i>Lam.</i> , Trochidae	Turbinidae	Trochidae	Lam. Turbinidae.
16. Deslongchampsia .....	Deslongchampsia, <i>M. Cuy</i> , 1850, Sub-genus of <i>Emarginula</i> , Fissurellidae	—	<i>M. Cuy</i> , Fissurellidae	—	<i>M. Cuy</i> , 1849, Patellidae.
17. Diarthema .....	Diartema, <i>Pfette</i> , 1864, Chenuopodidae	—	<i>Pfette</i> , Aporhaidæ	—	—



	Fischer.	Tygon.	Tate.	Stoliczka.	Morris and Lycett.
18. Discohelix .....	Discohelix, <i>Dunk.</i> , 1847, Sub-genus of <i>Eomphalus</i> , <i>Sow.</i> , Solaridae	<i>Dunk.</i> , Solaridae, between Onustidae and Scalaridae	<i>Dunk.</i> , Solaridae, between Littorinidae and Calyptraeidae	<i>Dunk.</i> , Solaridae, between Onustidae and Littorinidae.	—
19. Ditrema, <i>Deslongchamps</i> .....	—	<i>Desl.</i> , Pleurotomaridae	<i>Desl.</i> , Haliotidae, Sub-fam. Scaevellinae	—	—
20. Ditrema .....	—	<i>Piette</i> , 1874, Cerithiidae	—	—	—
21. Eumarginula .....	<i>Lam.</i> , Fissurellidae	<i>Lam.</i> , Fissurellidae	—	<i>Lam.</i> , Fissurellidae	<i>Lam.</i> , 1801, Fissurellidae.
22. Eucyclus = <i>Amboya</i> .....	—	—	—	—	—
23. Eulima .....	<i>Eulima</i> , <i>Risso</i> , 1826, Eulimidae	<i>Risso</i> , 1826, Eulimidae	Pyramidellidae	<i>Risso</i> , 1826, Eulimidae, Sub-fam. Euliminae	<i>Risso</i> , 1826, Pyramidellidae.
24. Euspira .....	<i>Euspira</i> , <i>Ag.</i> , 1837, <i>M. and L.</i> , 1850, Sub-genus of Ampullina, <i>Lam.</i> , Naticidae	<i>Ag.</i> , <i>M. and L.</i> , Naticidae	Naticidae, not mentioned by S. P. W.	<i>Ag.</i> , Sub-fam. Naticinae	<i>Ag.</i> , Sub-genus Naticidae.
25. Eustoma .....	<i>Eustoma</i> , <i>Piette</i> , 1855, Cerithiidae	<i>Piette</i> , 1855, Cerithiidae	<i>Piette</i> , Cerithiidae	<i>Piette</i> , Sub-fam. Cerithiinae.	—
26. Exelissa = <i>Kilvertia</i> , <i>Lyc.</i> .....	<i>Exelissa</i> , <i>Piette</i> , 1861, Cerithiidae	—	<i>Piette</i> , Cerithiidae	<i>Piette</i> , Sub-fam. Cerithiinae.	—
27. Fibula .....	<i>Fibula</i> , <i>Piette</i> , 1851, Sub-genus of Cerithella, <i>M. and L.</i> , Cerithiidae	<i>Piette</i> , 1857, Cerithiidae	<i>Piette</i> , Cerithiidae	<i>Piette</i> , Sub-fam. Cerithiinae.	—
28. Fissurella .....	<i>Fissurella</i> , <i>Brag.</i> , 1789, Fissurellidae	<i>Lam.</i> , Fissurellidae	—	—	<i>Lam.</i> , 1810, Fissurellidae.
29. Fusus .....	<i>Fusus</i> , <i>Lam.</i> , 1801, Fasciolaridae	<i>Lam.</i> , Sub-fam. Fusinae	Muricidae	Muricidae, Sub-fam. Fusinae	<i>Lam.</i> , 1801, Muricidae.
30. Kilvertia = <i>Exelissa</i> , <i>Piette</i> .....	<i>Lotia</i> , <i>Gray</i> , 1842, Delphinulidae	<i>Gray</i> , Littorinidae, between Neritidae and Lotellidae	—	Littorinidae, between Umbonidae and Turbinidae	—
31. Lotia .....	<i>Lotia</i> , <i>Gray</i> , 1842, Delphinulidae	<i>Gray</i> , Littorinidae, between Neritidae and Lotellidae	—	Littorinidae, between Umbonidae and Turbinidae	—
32. Littorina (Tectaria) .....	<i>Littorina</i> , <i>Fér.</i> , 1821, Littorinidae	<i>Fér.</i> , Littorinidae	including Tectaria, &c.	Tectaria, &c.	—
33. Manapora .....	<i>Manapora</i> , <i>Piette</i> , 1876, ? Cypriidae	<i>Piette</i> , 1876, ? Cypriidae	—	—	—
34. Mathilda .....	<i>Mathilda</i> , <i>Semper</i> , 1865, ? Turritellidae	<i>Semper</i> , Turritellidae	Pyramidellidae	—	—
35. Monodonta .....	<i>Monodonta</i> , <i>Lam.</i> , 1799, Trochidae	<i>Lam.</i> , Trochidae	Turbinidae	Trochidae (doubts <i>Monodonta</i> being Jurassic)	<i>Lam.</i> , 1801, Turbinidae.
36. Natica .....	<i>Natica</i> , <i>Adanson</i> , 1757, Naticidae	<i>Lam.</i> , Naticidae	Naticidae	Naticidae, sub-fam. Naticinae	<i>Adan.</i> , 1757, Naticidae. Neritidae.
37. Neridomus .....	<i>Neridomus</i> , <i>M. and L.</i> , 1850, Neritidae	<i>M. and L.</i> , Neritidae	—	—	<i>Defr.</i> , 1825, Pyramidellidae.
38. Nerinea .....	<i>Nerinea</i> , <i>Defrance</i> , 1825, Neritidae	<i>Defr.</i> , Pyramidellidae	—	<i>Defr.</i> , 1825, Pyramidellidae	<i>Defr.</i> , 1825, Cerithiidae.
39. Nerita .....	<i>Nerita</i> , <i>Adans.</i> , 1757, Neritidae	<i>Lam.</i> , Neritidae	—	<i>Adan.</i> , 1757, Neritidae	<i>Lam.</i> , 1758, Neritidae.

	Fischer.	Trigon.	Tate.	Stoliczka.	Morris and Lycett.
40. Neritopsis .....	Neritopsis, <i>Grat.</i> , 1832, Neritopsisidae	<i>Grat.</i> , Neritidae	Neritopsisidae, between Cancelleriidae and Pyramidellidae	1832, Vorticoidae (Neritopsisidae) between Naticidae and Volutinidae	<i>Grat.</i> , 1840, Neritidae.
41. Onustus .....	Xenophora, <i>F. de W.</i> , 1807, Xenophoridae	<i>H</i> and <i>A. Ad.</i> , Onustidae	—	Onustidae	—
42. Patella .....	Patella, <i>Linna.</i> , 1757, Patelidae	<i>Linna.</i> , Patelidae	Patellidae	Patellidae	<i>Linna.</i> , 1758, Patelidae.
43. Phasianella .....	"La plupart des prétendus <i>Phasianella</i> des T. J., sont des <i>Bourguetia</i> ," <i>Pileolus, Cookson, G. B. Sow.</i> , 1823, Neritidae	<i>Lam.</i> , Phasianellidae	Turbinidae	Phasianellinae	<i>Lam.</i> , 1812, Turbinidae.
44. Pileobus .....		<i>Cooke.</i> , Neritidae	—	<i>Cooke.</i> , Neritidae	<i>G. B. Sow.</i> , 1823, Neritidae.
45. Pileopsis = Capulus .....					
46. Pitonillus .....	Umbonium, <i>Link.</i> , 1807 = <i>Pitonillus</i> , <i>Mont.</i> , and <i>Rotella</i> , <i>Lam.</i> , Trochidae	<i>Mont.</i> , Rotellidae	Cyclotomidae, <i>S. P. W.</i> , who says = <i>P. Helicina</i> , <i>Lam.</i>	Pitonillus—Umbonidae	—
47. Pleurotomaria .....	Pleurotomaria, <i>Defr.</i> , 1821, Pleurotomariidae	<i>Defr.</i> , Pleurotomariidae	Sub-fam. Scissurellinae	<i>Defr.</i> , 1821, Pleurotomariidae	<i>Defr.</i> , 1825, Pleurotomariidae.
48. Pseudomelania .....	Pseudomelania, <i>F. and C.</i> , 1862, Pseudomelaniidae	<i>Pictet</i> , Euliniidae	Pyramidellidae	<i>P. and C.</i> , 1862, Eulimidae	—
49. Pterocera .....	Pterocera, <i>Lam.</i> , 1799, Strombidae	<i>Lam.</i> , Strombidae	—	—	<i>Lam.</i> , 1801, Strombidae.
50. Purpurina .....	Purpurina, <i>D'Orb.</i> , 1850, Littorinidae	<i>D'Orb.</i> , ? Purpurinae	Cancellaridae	? Trichotropidae	—
51. Purpuroides .....	Purpuroides, <i>Lyc.</i> , 1848, Murielidae	<i>Lyc.</i> , Sub-fam. Purpurinae	—	<i>Lyc.</i> , 1848, Sub-fam. Purpurinae	<i>Lyc.</i> , 1848, Buccinidae.
52. Rimula .....	Rimula, <i>Defr.</i> , 1819, sub-genus of <i>Emarginula</i> , Fissurellidae	<i>Defr.</i> , Fissurellidae	See 'Man. of Mollusca, p. 274, 4th edition	—	<i>Defr.</i> , 1827, Fissurellidae.
53. Rissoa .....	—	Rissoidae	<i>Frim.</i> , Rissoidae	—	—
54. Rissoina .....	Rissoina, <i>D'Orb.</i> , 1840, Rissoidae	<i>D'Orb.</i> , Sub-fam. Rissoinae	<i>D'Orb.</i> , Rissoidae	<i>D'Orb.</i> , Sub-fam. Rissoinae	<i>D'Orb.</i> , 1842, Littorinidae.
55. Rotella .....	= Umbonium, <i>Link.</i>	<i>Lam.</i> , Rotellidae	—	—	—
56. Solarium .....	"Les espèces indiquées dans <i>F. de W.</i> sont prob. a <i>Straparollia</i> ," <i>Spingera</i> , <i>D'Orb.</i> , 1850, sub-genus of <i>Alaria</i> , <i>M. and L.</i> , Chenopodiidae	<i>Lam.</i> , Solaridae	<i>Lam.</i> , Solaridae	Solaridae	<i>Lam.</i> , 1801, Turbinidae.
57. Spingera .....		<i>D'Orb.</i> , Strombidae	—	—	—
58. Stomatia .....	Straparollus, <i>Mont.</i> , 1810, p. 829, as a palaeozoic genus only—? Delphinulidae	<i>Halb.</i> , Stomatellidae	Haliotidae	Stomatidae	<i>Lam.</i> , 1801, Pleurotomariidae.
59. Straparollus .....		<i>Mont.</i> , Solaridae	= Eumorphalus, <i>Sow.</i> , Solaridae	= Eumorphalus, <i>Sow.</i> , Solaridae	—

	Fischer.	Tryon.	Tate.	Stoliczka.	Morris and Lycett.
60. Tesserolax .....	—	Gabb, Strombidae	= Alaria, M. and L.	—	—
61. Trochotoma .....	Trochotoma, Desl., 1842, Lyc.	Pleurotomariidae	Scissurellinae	Desl., 1841, Pleurotomariidae	Lyc., Pleurotomariidae.
62. Trochus .....	—	—	—	—	—
63. Turbo .....	—	—	—	—	—
64. Turritella .....	Turritella, Lam., 1799	Lam., Turritellidae	Turritellidae	Lam., Turritellidae	—
65. Umbrella .....	—	—	—	—	? Umbrella, Patelidae.
66. Vermetus .....	Vermetus, Adam., 1757, Vermetidae	—	—	—	—
67. Vermicularia .....	Vermicularia, Lam., 1799, subgenera of Vermetus, Vermetidae	Vermicularia, Lister, Vermetidae	—	—	—

<sup>1</sup> Placed under Annelida in Morris' Catalogue, 1854; e.g. *T. compressa*, Y. and B. = *Vermetus tumidus* and *concinus* Sow., I. O. Blue Wick, Yorkshire; and *V. nodosus*, Phil., I. O. Grey Limestone, Scarborough; Ponton, &c.

N.B.—The orthography of each author is preserved; hence the difference of spelling the same word. Moreover, it should be borne in mind that the above list must not be regarded as an absolutely complete generic list of all the British Jurassic Gasteropoda with the synonyms of each. On the other hand, such genera as *Fusus* and *Pterocera* are provisionally retained, though it is believed that no species belonging to them are found in our Jurassic rocks.



PART I.

---

GASTEROPODA OF THE INFERIOR OOLITE.



## INTRODUCTION.

THE vertical limits of the Inferior Oolite in England, as far as the Gasteropoda are concerned, lie between the Fuller's Earth, where that series is developed above, and the Upper Lias below. By some authorities the Fuller's Earth has been regarded as pertaining more to the Inferior than to the Great Oolite. Very little seems to be known of its Fauna, but its argillaceous character serves to connect it more with the Great Oolite than with the Inferior Oolite. Be this as it may, there are so few Gasteropoda that the inclusion or exclusion of the Fuller's Earth within the assigned limits is a matter of very little consequence. Further north, where the Fuller's Earth altogether fails, the upward boundary becomes a little indefinite for a time, especially in North Oxfordshire, &c. ; but, fortunately, these doubtful beds contain very little bearing upon our subject. In Northamptonshire and Lincolnshire the uppermost beds of the Lincolnshire Limestone must be regarded as the upper limit of the Inferior Oolite in that direction, and this arrangement carries us to the Humber. In Yorkshire the Scarborough or Grey Limestone is the highest bed of Inferior Oolite age which is known to contain marine fossils.

Turning now to the lower boundary there seems to be a general opinion that the Sands of the Inferior Oolite should be restored to their old position as part of that series, which will, therefore, include the Cephalopoda-bed of the Cotteswolds and its Dorsetshire equivalents. As a matter of fact there are but few Gasteropoda in sufficiently good condition in these essentially transition beds between the Lias and the Oolites to make their acquisition of much value, and consequently but few specimens are likely to be selected for description from them.

The main mass of the Gasteropoda of the Inferior Oolite is to be found in the various limestones, more or less oolitic, and sometimes irony and arenaceous, which lie between the equivalents of the Gloucestershire Cephalopoda-bed and the base of the Fuller's Earth. Portions of this region constitute a really rich hunting ground, and, where the whole is fully developed, include three, if not four, well-known life zones, viz. the zone of *Am. Murchisonæ*, the sub-zone of *Am. Sowerbyi*, and the zones of *Am. Humphriesianus* and *Am. Parkinsoni*. These zones or life horizons are not made out with equal clearness in all places, partly, perhaps, from local causes of obscurity, but mainly, I am inclined to think, from the

absence or feeble development of beds representative of these zones in particular places. The zones of *Am. opalinus* and *Am. Sauzei* must be regarded as of subordinate importance in this country. Moreover, even if the Fauna of a particular zone is present, the Ammonite which gives its name to the zone may not be present. In Dorsetshire such an absence rarely happens, because there we are dealing with an essentially Cephalopod facies, but in such deposits as the Lincolnshire Limestone, usually referred to the *Sowerbyi* sub-zone, it is not always easy to ascertain the horizon of beds in particular quarries.

On the whole, I have concluded that the gaps which separate these four zones are of unequal value, and would propose to divide the Inferior Oolite into two main divisions. The lowest division includes the sub-zone of *Am. Sowerbyi*, the zone of *Am. Murchisonæ*, and the reputed zone of *Am. opalinus*, all characterised by a well-marked group of keeled Ammonites. As regards the Cephalopoda it has affinities with the Upper Lias, or Toarcian. This lower of the two grand divisions of the Inferior Oolite might be known generally as the zone of *Ammonites Murchisonæ* in its extended sense, or we might simply call it THE LOWER DIVISION OF THE INFERIOR OOLITE, and this is what I should propose to do in any tabular arrangement which may be ultimately adopted for illustrating the vertical distribution of the Gasteropoda.

Our upper division has a very different Ammonite Fauna. The allied groups (genera, according to some) of *Sphæroceras*, *Stephanoceras*, and *Cosmoceras* are the prevailing forms, though by no means to the exclusion of all others. Moreover this great change in the Ammonite Fauna appears to coincide with certain worn and bored surfaces, indicating a period when deposits ceased, and when, perhaps, a certain amount of destruction was effected, pointing to a change of physical condition and to a considerable lapse of time. I am not aware how far local geologists would bear me out in this assertion, but we shall have an opportunity for testing it more closely when we come to the details of the four main topographical divisions of the Inferior Oolite. THE UPPER DIVISION OF THE INFERIOR OOLITE, therefore, comprises what is usually known as the zones of *Am. Humphriesianus* and *Parkinsoni*, which may be separated in some cases, but which apparently inosculate to a very considerable extent. It so happens that some of the very richest shell beds in Dorsetshire occur at the junction of these two zones, and their fossils have been assigned by some to the *Humphriesianus*-zone, and by others to the *Parkinsoni*-zone. Hence the advantage of a classification which does not attempt, in all cases, a division between these two.

It will be remembered that in the Cotteswolds Dr. Lycett adopted certain species of Brachiopoda for his zonal arrangements, but, owing to the apparent absence of *T. fimbria* in Dorsetshire, this plan is not satisfactory. Roughly speaking our Lower Division would comprise the *fimbria*-stage of Lycett, with the addition of



the *cynocephala*-stage,<sup>1</sup> and our Upper Division the *spinosa*-stage. As a rule the Lower Division is much the thickest in the neighbourhood of the great escarpments, whilst in the West Midlands it fails altogether on the dip in many places, so that the Upper Division rests directly on the Lias in the absence of the Lower Division. In Dorsetshire it is sometimes the Upper and sometimes the Lower Division which is best developed in a particular quarry or limited neighbourhood, but I have failed hitherto in detecting any rule bearing on the point.

Indeed there is very considerable irregularity and uncertainty in the Inferior Oolite, though less, perhaps, than in beds of Corallian age. Yet the four great districts display a marvellous difference both in their Gasteropod Fauna, due, perhaps, to general difference of facies, and also in their composition. Two features are fairly common to the Inferior Oolite throughout England, viz. that the mechanical impurities of the limestones are sandy, and that there is a great tendency to ferruginous deposits, especially in the Lower Division, which is much more irony than the upper one. Fawn-coloured limestones prevail, but some beds of the Cotteswolds, and also of the Lincolnshire Limestone, are exceptions, being very pale in colour. The so-called "Oolite Marl" of the Cotteswolds is not usually a marl in a lithological sense, but simply a calcareous paste, which has very likely been derived from the waste of coral. The lithology of the beds of Inferior Oolite age in Yorkshire, excepting the Whitwell and Cave Oolites, is very exceptional in comparison with the usual types which prevail throughout the rest of England.

But if the lithology of the beds varies greatly, the difference in their development is still more extraordinary. Where the beds are thinnest there, as a rule, the fossils, especially the Gasteropoda, are the most numerous. We can easily understand some of the causes which have produced this result. Given, for instance, a certain length of time, during which a series of beds have been undergoing deposition, if the material of which they are constituted is thickened by large additions of mineral débris we could almost imagine a time might arrive when looking for a fossil would be like looking for a needle in a bundle of hay. In most places outside the Yorkshire area, instead of mineral débris the beds are thickened by calcareous débris, mainly secreted by organisms in the first instance. Such débris may appear in the form of comminuted shelly matter, or as a calcareous paste, or as an oolitic granule. It is thus that the beds of Inferior Oolite in the Cotteswold escarpments are, for the most part, thickened. More rarely, and never to any important extent, the beds are thickened by an actual growth of coral *in situ*. There are three such bands—the name "reef" is scarcely applicable—in the Cotteswolds, and there can be no doubt that such belts of coral have exercised

<sup>1</sup> The species of Gasteropoda in the *cynocephala*-stage of the Cotteswolds are so few in number that it is hardly worth while making a separate division for these.

an important influence on the Fauna. There appears to be a really large coral growth in the Upper or Ragstone division of the Inferior Oolite on Dundry Hill. So far as I know, this is the only accumulation in beds of this age throughout England to which the term "reef" could be fairly applicable.

But although the remains of actual coral growth now presented to us are scanty, there can be little doubt that the Inferior Oolite was deposited when a considerable growth of coral existed in some places, and mostly in the direction of the prolongation of the escarpment. It must of course be borne in mind that we merely see the truncated ends of the beds along the line of strike, and that these beds have all extended much further in a direction opposite to that of the prevailing dip. Taking the Cotteswold area, for instance, as an example, the westward prolongation of the Inferior Oolite from such a place as Leckhampton might, and most likely did, extend over what is now the vale of Gloucester, towards the high lands of the west, which would be the direction of the shore of that period. It was most probably on fringing reefs connected with a shore so situated that the main mass of actual coral was being accumulated. And this growing coral not only fostered a peculiar Fauna, but also furnished to the waves no small amount of the calcareous mud, which, in the form of paste or granules, constitutes a large proportion of the Inferior Oolite as it is now preserved to us. The long east and west axis of the Mendips would form an island in the Inferior Oolite sea of the south-west, whilst its axial prolongations would form shallows or submarine ridges such as that so well exposed at Vallis, near Frome, on which several feet of a rubbly variety of the upper beds of Inferior Oolite may be seen to repose. A little way off, on the north and south flanks of this Mendip island, are considerable accumulations of impure calcareous sediment of Inferior Oolite age, almost devoid of fossils, and yielding building stones (Freestone quarries). In Dorsetshire, on the other hand, with which South Somerset may be included to a certain extent, the signs of coral reef are small, and where Cephalopoda are very numerous the conditions must have been very different; but this will be seen more fully when the details of the several districts are given.

What I particularly wish to emphasize just now is the extraordinary irregularity and marked contrast in the several portions of the Inferior Oolite, and, by consequence, of its fossil contents. This peculiarity is on the whole favorable to variety in the forms of life, or, stated in other terms, the more varied the facies the more numerous will be the forms in a given series of beds. This, I think, especially affects Gasteropoda, which are easily influenced by change of physical conditions within a given area, such physical conditions being indicated by the nature and varying volume of the deposits.

Despite its variability and local attenuation the Inferior Oolite is nearly continuous in its outcrop from Bridport Harbour on the Channel to Blue Wyke on

the North Sea with the exception of a short break in Yorkshire. But about half-way between these two points, in the very centre of England, the deposits of this age are very meagre, and yield scarcely any Gasteropoda, indeed but few fossils of any sort. That portion of the outcrop which lies between Banbury and a little east of Blisworth represents this series in its most degraded condition, and at the point where the new railway to Northampton diverges from the old line (north of Roade station) a few feet of unfossiliferous sand is all that intervenes between Bathonian beds and the blue shales of the Upper Lias. I have very little doubt that if we could follow the beds for a short distance on the dip (*i.e.* to the south-south-east) it would be found that the Inferior Oolite had disappeared entirely. We are therefore prepared for the entire absence of the Inferior Oolite throughout the south-east of England, as proved by numerous borings, and we perceive that this south-easterly attenuation, which has been noted at several points in the midland and west midland districts, is but the prelude to entire extinction.

But to return to the outcrop, this extreme thinning and change of beds in the centre of England is no doubt due to the configuration of the old land surface at the time of the deposition of the Inferior Oolite. Into these physical details there is no need for us to enter on the present occasion; it is enough for our purpose that a markedly new phase of the Inferior Oolite is gradually attained in the country which lies to the east of the main line of the London and North-Western Railway. The line as thus indicated may be said roughly to divide the two great regions of the Inferior Oolite from each other, that on the north-east being on the whole of a less marine character than the more typical and better known region to the south-west. But, just as the Cotteswold type differs from that of Dorsetshire, so in the great north-eastern division does the Northampton-Lincoln type differ from that of Yorkshire.

Hence we may divide the Inferior Oolite of England geographically into four principal districts as follows:

No. 1. *The Dorset District*, including part of Somerset in the direction of the Mendips.

No. 2. *The Cotteswold District*, extending from the neighbourhood of the Mendips to a line across the centre of England approximately indicated by the London and North-Western Railway.

No. 3. *The East Midland District* representing the outcrop of beds of Inferior Oolite age in Northants (east of the above line), Rutland, Lincoln, and perhaps south-east Yorkshire as far as the Pocklington axis.

No. 4. *The Yorkshire Basin* constituting an isolated area and presenting many peculiar features.

Of course there may be some room for difference of opinion as to the boundaries of these four areas or districts, but generally speaking each of them is characterised

by the predominance of certain facies, and this peculiarity gradually loses its distinctive character, and frequently the beds their fossiliferous wealth, as the confines of the adjoining area are approached. Hence I do not feel called upon to indicate the boundaries too absolutely, as if one were defining the limits of a parish or a polling district, though something of the sort may be attempted in giving the details of the four great districts. As regards the name of the second district it certainly includes more, both to the north and to the south, than the actual Cotteswold Hills. Hence our second district is not precisely coterminous with the Inferior Oolite of the Cotteswolds. Moreover, there is another difficulty in this connection, viz. where to locate the very exceptional development at Dundry. Both the facies and lithology of those fossiliferous beds recall some of the most typical of the Dorsetshire sections, in spite of their lying well to the north of the Mendips. But on the other hand the large development of coral in the *Parkinsoni*-zone quite distinguishes this remarkable outlier, which topographically must be included within the second district, unless we are to regard it as sufficiently important to constitute a region by itself.

Now, the Dorset district possesses an essentially Cephalopod facies in the main with, as we have already seen, a thin development of sediment. These conditions seem to have been eminently favorable to the growth of Gasteropoda, and the subsequent mineral changes have also been favorable to their preservation as fossils. Hence it is to the collections from these beds that we must look, not only for the greatest number of species, but also for the best preserved specimens on which we must depend for the illustration of this Memoir. In fact, if all the available Gasteropods of the Inferior Oolite were as well preserved as are those from the best localities in Dorsetshire, the task I have undertaken would prove a much easier one than is likely to be the case. The essentially Cephalopod character of the facies is maintained as regards the Lower Division, even into South Somerset,<sup>1</sup> but the Upper Division, or equivalent of the Cotteswold Ragstones, already begins to fail in Ammonites; though the shell-beds swarm with Brachiopoda and *Trigonia* together with a moderate supply of the Gasteropoda peculiar to the Upper Division.

In the Cotteswold district the deposits are so bulky that it would be difficult to name any one facies as markedly predominant. The three thin "coral reefs," if indeed they are worthy of such a grandiose name, mark the more classical portion of the district which extends from the neighbourhood of Stroud to the neighbourhood of Cheltenham. Hence the facies is partly coralline; but there are also examples of the brachiopod and echinoderm facies in abundance. Ammonites are comparatively rare, and, as far as I can ascertain, above the Cephalopoda-bed (zone of *Am. radians*), of very few species. The Lower Division is better supplied with Gasteropoda than the Upper Division, or Ragstones, but these shells cannot be said

<sup>1</sup> The axis of the Mendips is taken as the division between North and South Somerset.

to be numerous as a class or particularly well preserved, many appearing in the condition of casts. The "Oolite Marl" yields a fairly respectable list of Gasteropoda, and some of these are really in good condition, well preserved in fine white calcite, so as to constitute a valuable acquisition to the cabinet. Mr. Brodie also has some good specimens of Gasteropoda, mostly small, from the freestones, which bear some resemblance to the Fauna and facies of the Lincolnshire Limestone. On the whole, however, the Cotteswold area of the Inferior Oolite is rather disappointing, and if it were not for the abundance of *Nerinea* on certain lines in the "Oolite Marl" and associated beds, and the occurrence of this genus to a less extent in the "Pea-grit" below and the "*Clypeus-grit*" above, the ground would be somewhat poor hunting for those in search of Gasteropods. It has generally been held, and I think justly, that these shells are in some way associated with coral growth, and this seems all the more probable when we bear in mind that the No. 1, or Dorset district, notwithstanding its wealth of Gasteropods, has not yielded a single *Nerinea* to collectors, so far as my experience goes. The genus *Nerinea* has been traced as far as Radstock in the uppermost beds of the Inferior Oolite, but south of the Mendips it seems to be entirely absent, and this is also the case with beds on the same horizon in Normandy.

In the East Midland district, if we except the development of certain estuarine and ferruginous deposits, the Inferior Oolite is still mainly calcareous. The Lincolnshire Limestone is remarkably devoid of Cephalopoda, and the facies, where any abundance of fossils occurs, is described by Professor Judd as partly coralline and partly shelly. With few exceptions the Gasteropoda are small, but excessively numerous in certain places, and the genus *Nerinea* is well represented throughout. It would be difficult to show a greater contrast than that which exists between the Lincolnshire Limestone, with its white Oolite, small shells, and total absence of Ammonites, and the Dorsetshire ironshot Oolites, so full of Ammonites and Belemnites that Mr. H. B. Woodward declares the entire Inferior Oolite of that region might be called a Cephalopoda-bed.<sup>1</sup> It is probable that the greater part of the Lincolnshire Limestone belongs to the Lower Division, though matters are more obscure here than in the south-west. The facies and general appearance of the upper beds of the Lincolnshire Limestone at Weldon, Wansford, Barnack, &c., has a strong resemblance to the Great Oolite as developed at Minchinhampton and elsewhere, but possibly this resemblance is in part superficial, and it may be that the freestones of the Inferior Oolite in the Cotteswolds, on a close comparison of species, may have more affinity with the Lincolnshire Limestone than is usually supposed.

<sup>1</sup> 'Proc. Geol. Assoc.,' vol. ix, p. 203, 1886.

## DETAILS OF THE DORSET-SOMERSET DISTRICT (No. 1).

The Mendip axis serves approximately as the northern boundary.

*Comparison with Normandy.*

There can be very little doubt that both the Upper Lias and the Inferior Oolite of Dorsetshire present considerable analogies with beds of the same age in Normandy. This, indeed, has been pointed out by Oppel and Waagen, the latter of whom included Dorsetshire in the Parisian basin as distinct from the Inferior Oolite of the whole of the rest of England.

As regards the Upper Lias we have only to compare the general section at Ilminster, given by the late Charles Moore,<sup>1</sup> F.G.S., with the section at Evrécy, given by Prof. Eugène Deslongchamps<sup>2</sup> to perceive that above the *margaritatus*-beds (Marlstone), there come the *Leptæna*-beds, and then that remarkable zone of nodules, or doggers, with Saurians, Fish, and Crustacea, succeeded by certain beds containing Cephalopoda characteristic either of the Upper Lias proper, or of the *insignis*-zone. At Ilminster the whole of this, judging from the above-quoted section, is contained in about eight feet six inches, whilst at Evrécy the thickness of the corresponding beds does not exceed thirteen feet. But now supervenes an element of great physical difference in the Yeovil sands, over 100 feet thick, which separate the *bifrons*-beds from the regular Inferior Oolite of Dorsetshire. It is not a little singular that, whilst the life-zones remain almost identical in the two countries, there should be no adequate physical representative of these Yeovil Sands in the Department of Calvados.

But whilst the life-zones present such a singular resemblance, their arrangement and classification have been by no means uniform. Let us consult the work of Deslongchamps already quoted, in order to see how variously the Inferior Oolite may be divided or subtracted from according to the views of various authors. The learned Professor of Caen then wrote that the "*système oolithique inférieur*" consists of (1) Infra-oolitic Marls, (2) Inferior Oolite, (3) Fuller's Earth, (4) Great Oolite. His *système oolithique inférieur* is in fact the equivalent of the whole of our Lower Oolites *plus* the Upper Lias. I have drawn attention to the point mainly in order to show the development of the lower portion of the Inferior Oolite in Normandy, and its attachment to the Upper Lias, according to certain views. For this purpose it will be necessary to analyse the "Infra-oolitic Marls" to see

<sup>1</sup> 'Proc. Som. Arch. and Nat. Hist. Soc.,' vol. xiii (1865-6).

<sup>2</sup> 'Études sur les étages jurass. inf.,' p. 75, 1864.

what they are made of, and also the so-called Inferior Oolite, which latter we shall perceive has a much more restricted meaning than with us. The following is an outline of their development in Normandy, abstracted from the previously-quoted work. Starting below the Fuller's Earth :—

1. The "White Oolite." This is said to be the normal deposit of the Inferior Oolite; it is of considerable thickness, varying from twenty-eight feet to nearly fifty feet. The following are amongst the species quoted :—*Am. Parkinsoni*, *dimorphus*, *subradiatus*, *Martinsii*, *Natica Bajocensis*, *Trochus duplicatus*, *Pleurotomaria mutabilis*, *Terebratula carinata*, *T. Morieri*, *T. Phillipsii*, *T. globata*, *T. sphaeroidalis*, *Rhynchonella plicatella*. This may be said to form the *Parkinsoni*-zone.

2. The "Ferruginous Oolite." This is the famous Oolite of Bayeux, or typical Bajocian. It is six feet thick, and divisible into three beds. The central bed is that in which *Am. Humphriesianus*, *Gervillei*, *Brongniarti*, and a crowd of Gasteropods occur. Above is a bed characterised by *Am. Niortensis* and large varieties of *Pl. mutabilis*, whilst *Ter. sphaeroidalis* is more abundant than in the middle bed. Finally, at the base is a nodular bed, which contains the above-quoted Ammonites of the horizon of Bayeux, and along with these *Am. Sowerbyi*, *cycloides*, and even genuine specimens of *Murchisonæ*; most of the latter are believed to be *remanié*. This is in the main the *Humphriesianus*-zone, and perhaps includes in the lower bed the sub-zone of *Am. Sauzei*.<sup>1</sup>

3. "Mâlière," or highest group of the "Marnes Infra-oolithiques." Between this important series of beds and the "Ferruginous Oolite," or true Bajocian, there is, in Normandy, a considerable hiatus marked by eroded surfaces and other signs of a partial unconformity. The "Mâlière" is formed of a series of beds of marly limestone, frequently penetrated with "chlorite," sometimes sandy and siliceous. The thickness varies from nine to twenty-nine feet. It frequently contains dark siliceous concretions. The fossils are *Am. Murchisonæ*, and especially *Am. "aalensis"* or "*concavus*," which in Normandy occurs only on this horizon. Here also occur *Lima heteromorpha* and *Terebratula pervalis* along with *Rhynchonella ringens* and *R. quadruplicata*. The characteristic Gasteropods are *Eucyclus capitaneus* and *E. pinguis* along with *Pleurotomaria actinophthalma* and *P. Baugieri*. The "Mâlière" constitutes a sort of transition between the "Marnes Infra-oolithiques" and the beds of Bayeux; and, according to Deslongchamps, the fossils of this horizon were sometimes cited by D'Orbigny in his Toarcian, sometimes in his Bajocian, varying with the locality observed.

It is not difficult to recognise in the "Mâlière" of the Norman geologists the *Murchisonæ*-zone of Dorsetshire plus the so-called *Sowerbyi*-zone, so well characterised by the innumerable varieties of *Am. concavus*. This forms the main mass of our Lower Division of the Inferior Oolite in Dorsetshire, is characterised

<sup>1</sup> See further on for a more detailed description.

throughout by sharp-keeled Ammonites, and contains an assemblage of Gasteropoda, which present considerable differences from those of the Upper Division. Such are its Liassic affinities that, as we have already seen, Eugène Deslongchamps formerly placed it at the head of his "marnes infra-oolithiques," whilst D'Orbigny assigned its fossils here to the Toarcian, there to the Bajocian, although in reality the species of the two horizons are for the most part distinct.

4. Zone of "*Am. primordialis*." In Normandy this is described as not usually much more than three feet thick, often less; it reposes conformably in most places on the marls with *Am. bifrons*. In some places occur a great quantity of Gasteropods and Bivalves having a facies thoroughly Oolitic; often in a poor state of preservation. *Rhynchonella cynocephala* is quoted from these beds.

In everything but thickness this horizon probably represents the Yeovil Sands with *Am. radians*, *Am. Moorei*, &c. (the Gloucestershire Cephalopoda-bed).

*Locality and position of the principal beds containing Gasteropoda.*

There are certain familiar names, well known to collectors of Inferior Oolite fossils, frequently to be seen on the specimens themselves in our museums, &c. As regards Cephalopoda, and especially Belemnites, these are so universally distributed, each group in its own order of succession, that in some places the entire section of the Inferior Oolite might be termed a Cephalopoda-bed. The same might almost be said of the Conchifera and Brachiopoda. The remains of the Gasteropoda, besides being much more difficult to procure, have rather a tendency to be confined to certain horizons; not absolutely, however, as a few specimens will, of course, be scattered throughout. The object of the present notice is simply to draw attention to the locality and position of certain beds remarkable for the number of Gasteropoda which they contain. In so doing the description of each section will be given with a view more especially to emphasize the geological position of such beds. Attention will be paid to the ordinary divisions where that is practicable, but without attempting any of those refinements of generalisation which have been deemed possible by Oppel, and still more so by his successor Waagen. I have already insisted on the fact that the Inferior Oolite, at all events in the Dorsetshire district, is capable of being placed under two well-marked divisions, and in each section the position of the dividing line will be indicated as carefully as the facts known to me may justify. For general purposes the following may be accepted as the zones of the Inferior Oolite, which have been traced, though never all in one place, throughout the Dorset district.

- |                        |                   |
|------------------------|-------------------|
| 1. Parkinsoni-zone     | } Upper Division. |
| 2. Humphriesianus-zone |                   |
| 3. Sauzei-zone         |                   |



- |                                 |                   |
|---------------------------------|-------------------|
| 4. Concavus- or "Sowerbyi"-zone | } Lower Division. |
| 5. Murchisonæ-zone              |                   |
| 6. Opalinus-zone                |                   |
| 7. Radians-zone (Sands)         |                   |

The *Sauzei*-zone is an appendage of the *Humphriesianus*-zone, and both are often but feebly developed, except in the neighbourhood of Sherborne. The *concavus*-beds represent the upper part of the Mâlière of Normandy, and the true *Am. Sowerbyi* is hardly ever found in them. The most mixed Fauna occurs in the "*Sauzei*-bed" of Osborne, and some might class it with the Lower Division.

BURTON BRADSTOCK.—This name is very well known to collectors, and fossils so marked may come from shallow quarries and cuttings in the neighbourhood of the village, or from the cliff which overhangs the English Channel. Between Burton Castle and the neighbourhood of Bridport Harbour there is an isolated massif made up of the *Yeovil Sands*, capped by the *Inferior Oolite Limestone*; and in one place, where the sequence is very complete, these are succeeded by a fragment of the *Fuller's Earth*. This massif presents a bold front to the English Channel, and has a length of one and three quarter miles, by an average width of about half a mile. It is unequally divided by the River Bredy, which separates "Burton Cliff" from the area to the north-west. The *Inferior Oolite Limestone* of Burton Cliff, containing the fossiliferous beds presently to be detailed, is elevated out of reach by reason of the great thickness of the "Sands," and it is only where masses of this hard capping fall upon the beach that the fossils themselves come within reach of the hammer. Hence their relative position has not in all cases been determined with precision. Nevertheless, there is one horizon in Burton Cliff which is so pre-eminent above all others for the number and beauty of its *Gasteropoda*, that fossils marked "Burton Bradstock" are most likely to have been derived from it.

The portion of the cliff west of the River Bredy is sometimes known as the Bridport Cliff, but generally speaking the fossils from here are not well defined as to geological horizon, though they chiefly belong to the rich bed before mentioned. Some of the fossils marked "BRIDPORT" come from here, but the term is applied rather loosely. The town of Bridport is at some distance from the coast, and is situated on the Middle Lias.

The sands of the *Inferior Oolite*, or, as Oppel calls them, the sands of the Lias, exposed in this noble sea-cliff, consist of yellow sands with numerous indurated layers of bluish calciferous grit, which are sometimes continuous and at other times occur as nodular masses. These beds contain but few *Gasteropoda*, and those for the most part so ill-preserved that they require but trifling notice. As is so often the case where sedimentary accumulations are of great vertical development, they are comparatively barren of life, partly, perhaps, because such areas were

unfavorable to its development, and partly because the mechanical sediments mask those of organic origin. I have before observed that the horizon may be roughly represented as the zone of *Am. radians*. The lower portions (not visible in this section) may probably be the equivalents in time of the *Jurensis*-beds, as identified by Tate and Blake in Yorkshire, whilst the upper portion may be taken to represent the *cynocephala*-stage of Lycett.

It so happens that in one place a complete section of the Inferior Oolite Limestone has slipped to the base of the cliff, and therefore we are fortunately able to effect an examination which would otherwise require a considerable, not to say dangerous, exertion. The following profile, therefore, though measured at the bottom, really represents the top of the cliff. It shows us the Inferior Oolite in a nutshell, and affords a clue to its development in this neighbourhood and to a certain extent throughout the Dorsetshire district. Its modest dimensions seem puny in comparison with the bulky Cotteswolds and the still thicker masses of the Yorkshire Oolites. Nevertheless, though small it is regular in sequence and the life-zones are fairly shown, better perhaps than in any one section of the Inferior Oolite throughout England. Doubtless there are deficiencies, and the *Parkinsoni*-zone is in preponderating force.

*Profile No. 1, see page 31.*—Taking these beds in ascending order and without too detailed a scrutiny, we perceive that above the main mass of "Yeovil Sands" there occur about seven feet of sand-rock and calciferous grits between two lines of very thin, smooth, sharply-keeled Ammonites. These, no doubt, are the beds referred to by Oppel, who says that he found here the beds of *Am. torulosus* in the form of sandy, light grey limestone charged with numerous organic remains, amongst which he collected *Am. torulosus*, *opalinus*, and *subinsignis*, *Turbo subduplicatus*, *Terebratula anglica*, and *Rhynchonella cynocephala*.<sup>1</sup>

Speaking from my own experience the fossils of this horizon are mainly confined to the vicinity of the upper line of *Am. opalinus*, which Oppel regards possibly as the equivalent of his zone of *Trigonia navis*. There is here a fossiliferous zone which teems with *Am. opalinus*, and I possess both the other species of Ammonites mentioned by Oppel from this place and most probably from the same horizon. *Rhynch. cynocephala* was also noted from here, and likewise a few species of Gasteropoda, but not enough to constitute what the local collectors call a "Univalve Bed."

The remainder of the section upwards consists of five blocks of limestone, which measure altogether about twelve feet in height. The most notable shell-bed in the lower portion is one in connection with the "irony nodule" bed, a well-marked physical horizon in this neighbourhood. Ammonites greatly resembling *Am. Murchisonæ* occur hereabouts, and there are a sufficient number of

<sup>1</sup> See Oppel, 'Juraformation,' p. 328, 1856-58.

## Profile No. 1.—BURTON BRADSTOCK CLIFF.

(Section complete.)

		Capping of Fuller's Earth.
UPPER DIVISION.	Parkinsoni-zone.	0' 6" P <sub>3</sub> Upper shell-bed with <i>Am. subradiatus</i> , &c.
		4' 0" Limestones with fossils of the <i>Parkinsoni</i> -zone sparingly distributed.
		1' 0" P <sub>2</sub> An ill-defined shell-bed with Brachiopoda and large <i>Am. Parkinsoni</i> .
		1' 4" Limestone.
		1' 0" P <sub>1</sub> <i>Terebratula sphaeroidalis</i> . Chief shell-bed. GASTEROPODA. <i>Astarte obliqua</i> , <i>Am. Parkinsoni</i> .
		1' 0" Limestone with few fossils.
	Murchisona-zone.	1' 9" Fossils becoming more numerous. Line of iron nodules: GASTEROPODA. <i>Am. Murchisonæ</i> .
		1' 6" Impure Limestone with few fossils.
		0' 3" Brash and Rock with <i>Am. opalinus</i> . GASTEROPODA.
		12' 4" Total. Calciferous grits and brown sand-rock of the Yeovil Sands.

<sup>1</sup> In interpreting this and the following profiles the reader should bear in mind—(1) That the proportionate thickness of the beds is not observed any more than convenience allows; (2) the relative thickness of the beds must be judged by the measurements, which do not claim to be more than fairly accurate; (3) the divisions shown do not in all cases agree with existing divisional planes; (4) the main object in all cases has been to emphasize the position of the chief beds bearing Gasteropoda.

Gasteropoda on this line to entitle it to the dignity of an "Univalve Bed." The fossils are mainly those characteristic of the Lower Division, and more especially of the *Murchisonæ*-zone; e.g. *Cirrus*, usually a fossil of a low horizon. The other Gasteropoda from here will be named in their due places. The upper portion of this in all probability shades off into the *concavus*-beds, or so-called *Sowerbyi*-zone, but as there are no special traces of Gasteropoda here we need not go further into the inquiry. There are signs of the so-called "*Sowerbyi*"-zone in a quarry on the north side of the Bredy, but I found no Gasteropoda there of any consequence.

Again, the line between the Lower and Upper Divisions of the Inferior Oolite cannot be laid down to an inch or two with absolute certainty in the cliff section. This doubt arises mainly from the feeble and imperfect development of the *Humphriesianus*-zone, a failure very characteristic of South Dorsetshire. As far as an inspection of this section goes there seems to be no independent development of the *Humphriesianus*-zone at all otherwise than as an adjunct to the rich-shell at the base of the *Parkinsoni*-zone ( $P_1$ ). This was noticed by Oppel, who, whilst alluding to the trifling thickness of the Inferior Oolite, speaks of the fossils of the *Humphriesianus*- and *Parkinsoni*-zones being found together in one and the same bed of Oolite. To a certain extent this is so, and if such a zonalist as Oppel admitted the fact the evidence in its favour must be very strong indeed.

We have then to consider the character of the shell-bed which I have distinguished as  $P_1$ . It is mainly situated towards the lower portion of the third block of limestone, and is by far the most important shell-bed in the Burton Bradstock Cliff. A portion of it also belongs to the next block, the split taking place through the midst. The result is that when the larger blocks break up there is a double surface presented to the collector's chisel. *Astarte obliqua* is very abundant, and there are also other species of *Astarte*, so that this is sometimes known as the *Astarte*-bed. The upper part of  $P_1$  is crowded with *T. sphæroidalis*, whilst in the lower part the *Astarte* is most abundant. It is in this lower part that the Gasteropoda of this shell-bed principally occur. Specimens of moderate-sized *Am. Parkinsoni* are by no means uncommon in the *Astarte* division of  $P_1$ , and may be found quite down to the base of the shell-bed. Sometimes, however, in the very base of the bed, and in that portion which belongs to the lower block, fair-sized specimens of *Am. Humphriesianus*, or a very closely allied *Stephanoceras*, may be found. It is just possible that there may be a slight unconformity between the two lines so that, here and there, specimens belonging to an older and lower zone are sometimes adherent to the main mass. In this way an uncompromising zonalist might seek to explain the apparent admixture. However that may be, it is perfectly certain that specimens of *Am. Parkinsoni* are to be found quite as low as any of the Gasteropoda hereafter to be described, and therefore I have no hesi-

tation in assigning all specimens from  $P_1$  of the Burton Bradstock Cliff to the lower division of that zone—which throughout this neighbourhood is richer than all the rest put together. *Am. Martinsii* is also abundant in this bed, and other Ammonites which are characteristic of this horizon.

According to my experience *Am. Martinsii* is a pretty faithful guide to the geological horizon of a particular bed when it occurs in any quantity. The position of this abundant development is low down in the *Parkinsoni*-zone, or in some cases we might say high up in the *Humphriesianus*-zone. If we accept for the moment the level of maximum development of *Am. Martinsii* for our datum line we shall find that here, at Burton Bradstock, *Am. Parkinsoni* descends rather lower than the former does, for instance, at Osborne, as we shall perceive subsequently. Hence we must bring the *Parkinsoni*-zone a little lower down here, since, not only does the section *Cosmoceras* exceed all other sections of the unwieldy genus *Ammonites* in  $P_1$ , but the real *Am. Parkinsoni* is there in abundance quite to the base of the bed, but only of moderate dimensions. I have been somewhat precise in respect of this bed, not only because it is "the fossil-bed" of Burton Bradstock and the neighbourhood, but because, in the excellent section contributed by Mr. Etheridge to Damon's 'Geology of Weymouth,' it is evident that this bed is regarded as being in the *Humphriesianus*-zone. This misconception is probably due to an exaggerated notion of the importance of the *Humphriesianus*-zone in South Dorset, and may have its origin in the opinion expressed by the late Dr. Wright as to the position of the "fossil-bed" at Bradford Abbas.

Although there is considerable variety in the mineral composition of  $P_1$ , yet the matrix of a majority of the Gasteropoda is a pale grey marly limestone, which is very characteristic of this bed wherever it occurs between Burton Bradstock and Bridport Harbour. According to the degree to which this bed is ironshot, browner tints, more characteristic of the Dorset Inferior Oolite, are seen to prevail. On the whole, however, the bed as here developed seems to work rather more kindly than is often the case, and as the fossils are in good spathic condition, it has often been possible to develop them with a considerable degree of accuracy. My collector, Mr. Bloomfield, has been very successful in this respect, and specimens of *Spinigera recurva*, sp. n., with most of the spines attached, and other good fossils have rewarded his efforts. As we shall perceive in the sequel the Gasteropod Fauna of this bed is very distinct, and may be traced for some distance in South Dorset, nor is it difficult to see what are its approximate equivalents in other parts of No. 1 District. Moreover, its Gasteropoda are clearly those of the Bajocian (understanding this term to include the *Humphriesianus*- and *Parkinsoni*-zones only). They are fairly different from the much lower Bajocian beds at Osborne, and present a striking contrast to those of the infra-Bajocian "fossil-bed" of Bradford Abbas, which, as we have already seen, belongs to Deslongchamps' "Marnes Infra-oolithiques." I

might say here, whilst dealing with this subject, that, although the term "Bajocian" as applied by D'Orbigny was in the main confined to the "beds of Bayeux," it has since been so generally applied to the whole Inferior Oolite that we might well call the "horizon of Bayeux" Upper Bajocian and all the rest Lower Bajocian. At any rate this would sound better than "Upper Inferior Oolite" and "Lower Inferior Oolite." Still it is not strictly accurate, and martinets might grumble: we had best restrict ourselves to Upper Division and Lower Division.

*Purpurina bellona*, D'Orb., a somewhat elongate variety, is not uncommon in this bed, and *Onustus ornatissimus*, D'Orb., is also characteristic. Both these genera are represented by very different species in the "fossil-bed" of Bradford Abbas. *Purpurina bianor*, D'Orb., and varieties or allied species, are also characteristic; and *Purpurina inflata*, Tawney, likewise occurs. *Alaria hamus*, Desl., and *Alaria Lorigeri*, D'Orb., or forms very near them, are fairly plentiful. On the whole, perhaps, the Normandy fossils are better represented in this bed than in any other, though in some respects the two Gasteropod horizons at Osborne may be still richer in forms identical or representative of those across the Channel.

P<sub>2</sub>. This might be called the *Terebratulula*-bed, from the abundance of what I take to be small varieties of *T. sphaeroidalis*; *Terebratulula Phillipsii* and *Waldheimia carinata* are also characteristic, or at any rate fossils that pass for such species. Conical forms of *Pleurotomaria* occur, and the specimens of *Am. Parkinsoni* are very large. Belemnites are very abundant. *Holcotypus*, a small rounded species, is tolerably abundant. There are Gasteropoda here too, but not in sufficient numbers to call for any special notice. This shell-bed occurs about the base of the second limestone block, and within a very short distance vertically from P<sub>1</sub>. Though well separated in the cliff section it is just possible that in some of the quarries hereabouts the two may coalesce.

P<sub>3</sub>. A somewhat greater width of oolitic limestone separates this, the topmost bed of the *Parkinsoni*-zone, from the shell-bed last before detailed; it is about five inches thick and contains a narrow species of Belemnite in considerable abundance. *Am. Parkinsoni* is rare but *Am. subradiatus* is decidedly plentiful, and there occurs a very thin Ammonite just at the top, which perhaps, may be regarded as a variety of *Am. subradiatus*. *Serpulae* and *Placunopsis* are adherent. Monomyaria are very abundant, especially *Lima pectiniformis* and *L. duplicata*. Many Myacids may be noted, and the little round *Holcotypus* (? *H. depressus*) is to be found in great numbers. Very few Gasteropoda were noted. Upon the surface at the top the small *Ostreae* and other shells of the *Fuller's Earth* above are adherent.

*Comparison of the Dorsetshire and Yorkshire Coasts.*

There is, perhaps, no portion of the Inferior Oolite throughout England which is so well illustrated as the *Parkinsoni*-zone of Burton Bradstock Cliff, even down to very minute details, and it is, of course, all the better for not being inflated with too much sedimentary matter. As this is the first glimpse of the Inferior Oolite in England, for one coming from the south it might perhaps produce an exaggerated notion of the importance of the *Parkinsoni*-zone.

One cannot help reflecting on the marvellous contrast presented by the section of the Inferior Oolite on the Yorkshire coast. Setting aside the enormous difference of physical development, we have in the *Nerinæa*-bed of the Yorkshire Dogger a fine development of the *Murchisonæ*-zone, and this is indeed the only bed of the Inferior Oolite which can be regarded as rich in Gasteropoda in that county. But owing to the difference of facies even the *Murchisonæ*-bed of Burton Bradstock Cliff has not much more resemblance to the Yorkshire Dogger than the beds of the *Parkinsoni*-zone have. It has many Ammonites and no *Nerinæas*, whereas the Yorkshire Dogger has many *Nerinæas* and hardly any Ammonites. If we carry the comparison a step higher we find the Cephalopoda of the *Humphriesianus*- or coronaten-zone abundant in certain portions of the Scarborough Limestone, whereas in Burton Bradstock Cliff this zone is aborted, or so overshadowed by the lower part of the *Parkinsoni*-zone as to produce no impression. Again, on the Yorkshire coast there is no palæontological representative of the *Parkinsoni*-zone, so that in all respects the contrast is most complete.

In every respect, therefore, the marine beds of the Inferior Oolite on the Yorkshire Coast differ surprisingly from those of Dorsetshire. Yet despite this difference the relative position of the life zones is always the same so far as the Cephalopoda afford the means for comparison. It remains to be seen how far this holds good for the Gasteropoda. The contrast between the species of Gasteropoda in our Lower and Upper Divisions is exceedingly marked throughout the Dorset District, where the abundance and excellent preservation of the Gasteropoda admit of the fact being proved to demonstration. Possibly the difference may be shown to a certain extent in the Cotteswold District (No. 2), but less clearly, I think, in the Yorkshire District (No. 4).

Reverting once more to the *Parkinsoni*-zone in Burton Bradstock Cliff, it seems to me that the Cotteswold divisions of the Ragstone are to a certain extent pre-figured in this exposure. Making due allowance for geographical distance and difference of facies, I think that  $P_1$  corresponds in the main to the Upper Trigonia Grit, though here fortunately the matrix is quite of a different character, hence lithologically there is no resemblance. Moreover, *Rhynchonella spinosa* does not

appear to make any show (I speak rather with hesitation on this point). There can be no doubt, however, that in most places throughout the Dorset-Somerset district, at all events from the sea coast as far as Castle Cary in south-east Somerset, wherever the Upper Division of the Inferior Oolite is at all well developed, a shell-bed rich in Gasteropoda is to be found about this horizon, and that in many cases it contains *Rhynch. spinosa*. We shall see this further on, and we shall also see that, in some places, there is a tendency to assume the lithological peculiarities of the Ragstone. If we grant that  $P_1$  prefigures the Upper Trigonía Grit, we shall have no difficulty in believing that the succeeding beds, including  $P_2$  and  $P_3$ , prefigure the *Clypeus*-grit, though not exactly corresponding as to details. Nevertheless, I consider that  $P_2$  is somewhere about the horizon of the *globata*-bed, whilst  $P_3$ , in the abundance of its Myacids, reminds us of the name given by Lycett, viz. *Pholadomya*-grit, to the uppermost beds of the Inferior Oolite in the Cotteswolds. These two beds have not yielded me many species of Gasteropoda here—nothing, in fact, of importance—but if they were well worked the case might be different.

The section above detailed affords us the key to the remainder of the mass of Inferior Oolite on its pedestal of Yeovil Sands in this vicinity. Still, there are differences, and in one small quarry south of the village of Burton Bradstock, where there is an exposure of about five feet, better traces of the *Humphriesianus*-zone seem to exist. A recent road-cutting, leading from the village to the sea coast, displays a complete section of the Inferior Oolite Limestone with the underlying impure Siliceous Limestones. Mr. H. B. Woodward, who was resurveying this district in 1885, writes as follows: "This excavation shows nearly the whole of the Inferior Oolite (here about fifteen feet in thickness), and the junction of it with the Sands beneath. . . . Many fossils were observed, although, owing to the difficulty of extracting them, if not to the fear of injuring the banks, few were collected. The entire Oolite is here a 'Cephalopoda-bed'; but the so-called Cephalopoda-bed of the Cotteswold Hills is no doubt represented by the upper portion of the Sands beneath. The lowest portion of this Oolite represents in a broad sense the zone of *Ammonites Murchisonæ* (including the beds with *A. concavus*); the highest portion represents the zone of *Ammonites Parkinsoni*. The zone of *Ammonites Humphriesianus*, which is to be found in some quarries east of Bridport, does not appear to be distinctly developed at Burton Bradstock, although the species is met with in the cliffs and road-cutting."

The above remarks will serve to afford an idea of those portions of the country away from the cliff. But, since many of the specimens procured by the most experienced collectors are obtained from old walls, or else from old disused quarries, where the fossiliferous blocks lie about in the midst of grass-grown sections, there will be a slight element of uncertainty as to the horizon of some of

<sup>1</sup> 'Proc. Geol. Assoc.,' vol. ix, p. 203, 1886.



the fossils marked "Burton Bradstock" and "Bridport." The majority, however, undoubtedly come from the horizon which I have distinguished as  $P_1$ .

BRIDPORT.—The town itself is on the Middle Lias, but within a moderate distance are some important exposures of the Inferior Oolite. Burton Bradstock bears  $2\frac{3}{4}$  miles S.E. The cliff between Bredymouth and Bridport Harbour 2 miles S. by E.; Vitney Cross Quarries 3 miles E.; Upper Lodgers Quarry  $3\frac{1}{4}$  miles E.N.E.; quarry at Poorstock Station  $3\frac{1}{2}$  miles N.N.E.; Outlier at Symondsbury  $1\frac{1}{4}$  miles W. by N.; Outlier at Chideock 2 miles W. by N. Some of these may have had more importance formerly than at present, but two of them have yielded many interesting Gasteropoda quite lately, viz. *Vitney Cross* and *Upper Lodgers*.

VITNEY CROSS (see Profile No. 2, p. 38).—There are two quarries here, distinguished as the *Limekiln Quarry* and *Knight's Quarry*. Both afford good hunting ground for fossils, but in the Limekiln Quarry the section is more complete.

This quarry is extremely interesting, as it serves for comparison with the development of the Inferior Oolite in Burton Bradstock Cliff, a distance of three miles. We find that the physical conditions are mainly the same; the volume of the limestones has not at all increased, the Inferior Oolite is still "in a nutshell," and the *Parkinsoni*-zone maintains its preponderance in every way.

The lowest bed visible is somewhere about the *opalinus*-zone, but no palæontological traces of that horizon are forthcoming. The block with the line of Ammonites resembling *Am. Murchisonæ* is a hard blue stone with much pyrites, and is far from being a pure limestone; there is a line of a large *Astarte* along with the Ammonites. The iron nodules serve as an excellent physical feature to guide us on this horizon. The bed above the iron nodules contains numerous Belemnites; it is in many places a hard, calcitic, ironshot stone like the ordinary Dundry matrix. In position it may represent the *concavus*- or *Sowerbyi*-beds, and probably forms the top of the Lower Division in this quarry, most probably in contact, or nearly so, with the base of  $P_1$ .

The lower half of  $P_1$ , which we may distinguish as the *Astarte*-bed, constitutes the base of the upper portion of the quarry; it is well developed, and contains, both here and in the adjoining quarry, a fine suite of Gasteropoda, tallying extremely well with species from the same bed in Burton Bradstock Cliff. Fine specimens of *Spinigera recurva*, and many of the characteristic univalves of Burton Bradstock and the neighbourhood of Bridport, may be found here, but the matrix is rather harsher to work. In Knight's Quarry large specimens of *Am. Parkinsoni*, and a small species of *Stephanoceras* are abundant; *Ancyloceras* also occurs. The lower half of  $P_1$  is separated from the upper half by about six inches of limestone without many fossils; it is rather thinly stocked, but contains a considerable number of *Ter. sphaeroidalis*, or what passes for that species.

One of the more remarkable features of the quarry is the great development of

## Profile No. 2.—VITNEY CROSS QUARRY.

(Section complete.)

		Capping of Fuller's Earth.	
UPPER DIVISION.	Parkinsoni-zone.	1' 9" P <sub>3</sub>	Upper shell-bed. <i>Belemnites</i> , <i>Trigonia</i> , &c. <i>Brachytrema</i> . <i>Onustus</i> .
		3' 3"	Calcareous rock with fewer fossils, chiefly Brachiopoda.
		1' 6" P <sub>2</sub>	Crowded with Brachiopoda of many species. Some Gasteropoda.
		2' 8"	Calcareous rock.
		1' 9" P <sub>1</sub>	<i>Terebratula sphaeroidalis</i> above. In two divisions. GASTEROPODA. <i>Astarte obliqua</i> below.
LOWER DIVISION.	Murchisonæ-zone.	1' 2"	Block containing in lower part a line of iron nodules.
		0' 8"	Blue block containing <i>Am. Murchisonæ</i> atop.
		1' 6"	Grey calciferous grits and hard brownish sand-rock.
13' 3" Total.		Yeovil Sands.	

It should be noted that not very far from here, in a southerly direction, traces of the *Humphriesianus*-zone have been found by Mr. H. B. Woodward; *i. e.* he obtained a fine specimen of *Am. Humphriesianus* in a certain quarry. See remarks on this point with reference to the Burton Bradstock section. Either a thin layer of an older rock is adherent to the shell-bed, or there is an admixture of forms.

P<sub>2</sub>, or the Brachiopoda-bed, the upper portion of which is a complete arabesque or shell-entablature; large specimens of *Trigonia costata* and other *Trigonia* occur. Brachiopoda are very numerous; *Rhynchonella spinosa*, *Waldheimia carinata*, *Terebratula Phillipsii*, and a few *T. sphaeroidalis* in the lower part. Several Gasteropoda were obtained from this bed in 1885. P<sub>3</sub>, the upper shell-bed just under the Fuller's Earth, is nearly two feet thick, and contains one or two peculiar Gasteropoda, and notably the only species of *Brachytrema* I have succeeded in discovering from the Inferior Oolite of the Dorset district.

LODERS.—An old quarry face at Upper Lodgers displays pretty much the same sequence as at Vitney Cross. At all events the *Astarte*-bed, P<sub>1</sub>, is the main source of the Gasteropoda which come from here, as is the case almost everywhere east of Bridport. The irony nodule-bed with the *Murchisona*-like Ammonite just below is in its place about two feet underneath, then grey calciferous grits and brown sand-rock, showing the lithology of the *opalinus*-zone, though apparently without its fossils.

BEAMINSTER.—This town is five and a half miles due north of Bridport. I do not know of any quarries in the town, but there are some in the neighbourhood. There are a few Gasteropoda marked "Beaminster" in the Buckman collection; and some have been sent to me from Mapperton, a village not far off. Judging from appearances, this is a neighbourhood where the *Parkinsoni*-zone has lost its predominance, and where such Gasteropoda as have been collected may be safely assumed to belong to the Lower Division, though to what stage of the Lower Division may not in all cases be clear. There is a quarry at Horn Park, one and a half miles north-west of Beaminster, showing nine feet six inches of limestone. The Lower Division here is five feet thick, and very full of Cephalopoda. The upper four feet six inches of this quarry consists of yellowish Oolite poor in fossils, which probably belongs to the Upper Division, though its rich shell-beds have disappeared. All this favours the supposition that "Beaminster" specimens may be set down either to the *concarvus*- (*Sowerbyi*-) zone or to the *Murchisona*-zone. There is an exposure likewise at a place called Wadden Hill (marked Stoke Knap in the map) not far from Horn Park, where the *opalinus*-zone appears to be fossiliferous, since I have a specimen of the *Am. torulosus* from here, and two or three indifferent Gasteropoda.

BROADWINSOR.—Three and a half miles north-west of Beaminster. This has been an important quarry for many years. The face of stone is about eight feet four inches thick, and presents no very definite shell-bed. There is abundance of *T. Phillipsii* in the upper beds, and of *T. sphaeroidalis* lower down. The whole is in the Upper Division and probably in the *Parkinsoni*-zone, thus forming a marked exception to all other quarries in this neighbourhood.

DRYMPTON, one and three quarter miles north of Broadwinsor.—Going still

northwards, this is the next exposure met with. It is a small quarry three miles south-west of Crewkerne Station. There is about six feet of stone in three blocks. The whole is probably in the *Murchisonæ*-zone, if not lower. *Waldheimia anglica* is very abundant, and the place is remarkable for very pretty species of *Trochus* or *Delphinula*. This is the most western point of any of the quarries noted.

HASELBURY (see Profile No. 3, p. 41).—One and three quarter miles north-east of Crewkerne Station. This is a place of considerable importance as a quarry, but it is more remarkable for *Echini* and *Conchifera* than for *Gasteropoda*. *Isocardia cordata* is a noteworthy fossil here, since its occurrence in Dorsetshire has not often come under my notice.

It must be allowed that Profile No. 3 is very inferior in interest, for our purpose, to the two preceding, since but few *Gasteropoda* are noted from this quarry. I have introduced it mainly to show the preponderating importance of the Lower Division, and especially of the *Murchisonæ*-zone in this area. The "massive shell-bed with keeled *Ammonites*" certainly represents nothing higher than the *concarus*- (*Sowerbyi*-) zone, whilst all the rest must be in the *Murchisonæ*-zone or lower. The *Gasteropoda* are probably on the same line as at Drympton, which I conceive to be towards the base of the *Murchisonæ*-zone.

*Résumé of the south-western half of the Dorset-Somerset District.*

On the coast and for some miles inland the Lower Division of the Inferior Oolite is only feebly represented as a limestone, and, although there is an interesting shell-bed, associated with a line of iron nodules, which may be traced for some miles, containing the fossils of the *Murchisonæ*-zone, yet the development and also the fossils of the Upper Division, and notably of the *Parkinsoni*-zone, greatly preponderate. Near Beaminster, and north of that town as far as Haselbury, the very reverse of this state of things obtains. With the single exception of the quarry at Broadwinsor all the fossiliferous exposures known to me are in the Lower Division, and for the most part low down in that division, which is thicker than towards the coast.

It now remains to consider the *north-eastern half* of the Dorset-Somerset District, and we commence our researches in the vicinity of *Yeovil Junction*.

EAST COKER.—Two and three quarter miles south-west of Yeovil Junction. I have not been here myself, but am informed that there is only about three feet of limestone. The fossils are those of the *Murchisonæ*-zone, and especially *Cirrus*.

STOFORD.—The limestone quarry is a few hundred yards west of Yeovil Junction. The Inferior Oolite Limestone is only a few feet thick, but affords a very complete section, which may be traced to the base of the Fuller's Earth. It is more

## Profile No. 3.—HASLBURY QUARRY.

		Section incomplete.
LOWER DIVISION.	Murchisonæ-zone.	1' 0" Top bed. No fossils noted.
		0' 3" Brash.
		2' 4" Massive shell-bed, with large Conchifera. Keeled Ammonites.
		2' 0" Massive creamy Limestones, with some shells. <i>Am. Murchisonæ</i> , <i>Lima Etheridgii</i> , and <i>Wald. anglica</i> , common.
		0' 11" Calcareous Rock.
		1' 6" Shelly towards the top with a few <i>Gasteropoda</i> . <sup>1</sup>
		1' 4" Base bed.
9' 4" Total.		Water in bottom of quarry.

<sup>1</sup> It is not always easy to separate and distinguish between the fossils of the *opalinus*-zone and those of the *Murchisonæ*-zone

or less a repetition, on a reduced scale, of the Bradford Abbas section. Gasteropoda from more than one horizon are far from scarce. The Lower Division preponderates.

*Stoford Sands Quarry*.—No Gasteropoda are known to me from here, but it is interesting as containing a shell-bed about forty feet below the Inferior Oolite Limestone with *Am. radians*, *Am. Moorei*, &c., plainly showing where the horizon of the Gloucestershire Cephalopoda-bed must be sought. Mr. H. B. Woodward considers that these shell-beds occur at more than one level in the Yeovil Sands.

BRADFORD ABBAS.—There has been more than one quarry worked in this parish; and it can hardly be doubted that many of the fossils from these quarries and from Stoford, &c., are labelled and quoted "Yeovil," which town happens to be on the Middle Lias.

Although there is only about twelve feet of limestone here, the life-history of the Inferior Oolite is well represented in this quarry, which may be compared with the cliff section at Burton Bradstock (Profile No. 1) of about the same thickness. I have no Gasteropoda from the lowest or *opalinus*-zone, if indeed it occurs here, but the Paving-stone bed is an excellent repository of the fossils of the *Murchisonæ*-zone, which may be also proved in the railway-cutting, a short distance to the south. Thirteen inches of stone in this quarry are the Dorsetshire representatives, in all probability, of most of the *fimbria*-stage of the Cotteswolds. This may be shown by the Ammonites. The resemblances between the Gasteropoda of the two regions is less obvious. Indeed, we are never so strongly reminded of the differences between the two districts as at Bradford Abbas, because it is here that the *Murchisonæ*-zone has been most successfully worked for fossils, so that comparisons are more possible than elsewhere.

The following is an extract from an Excursion Report of the Geologists' Association<sup>1</sup> with reference to this bed. "The 'Paving-stone bed' is a slabby ironshot Oolite, which comes off just above the 'Dew-bed,' and is used for gutters, &c. The true *Harpoceras*<sup>2</sup> *Murchisonæ* occurs here, as also the var. *Bradfordiensis*, S. S. Buckman. That author says of *H. Murchisonæ* that it marks a distinct zone which is just on the top of the Sands or passage-beds. This zone is about a foot thick at Bradford Abbas, but about three or four feet at Corton and Hawthorn Downs." At Bradford Abbas the Gasteropoda of this zone are in fairly good spathic condition, though not equal to the bed above. The matrix is a rather harsh calcareous rock, yellowish for the most part where the iron is peroxidised, and moderately ironshot. Sometimes the shells have perished considerably. It is not at all times certain that the fossils have not been mixed somewhat with those from the bed above, with which no doubt they are closely allied. Certain genera, however, are greatly predominant, such as *Cirrus*, though this is probably less

<sup>1</sup> 'Proceed.,' vol. ix, No. 4.

<sup>2</sup> Now called *Ludwigia*.

## Profile No. 4.—EAST HILL QUARRY, BRADFORD ABBAS.

(Section complete.)

		Position of the Fuller's Earth.
UPPER DIVISION.	Parkinsoni-zone.	6' 6" Whitish Limestone in several beds, with occasional specimens of <i>Am. Parkinsoni</i> , Brachiopoda, &c., and a few Gasteropoda, but no definite shell-beds.
		0' 6" Marl-bed with <i>Terebratula Morieri</i> and <i>Rhynch. parvula</i> , and small Gasteropoda.
		0' 6" Rotten-bed with large <i>Astarte</i> .
		0' 6" Irony stone.
	? H.-zone.	2' 0" These blocks of stone contain the chief "fossil-bed" in the so-called <i>Sowerbyi</i> -zone, GASTEROPODA. <i>Am. concavus</i> .
		1' 1" <i>Am. Murchisonæ</i> . GASTEROPODA. Paving-stone bed.
		1' 2" "Dew-bed.
		12' 3" Yeovil Sands.
	Murchisonæ-zone.	Total.
LOWER DIVISION.		

abundant than at Stoford and Coker. The species of *Amberleya*, too, are rather numerous, and differ somewhat from those of the *Sowerbyi*-bed; there are also species of *Onustus* allied to *O. pyramidatus*, Phil., which seem rather peculiar.

The real "fossil-bed" of Bradford Abbas occurs in two blocks. This stone when peroxidized is also a yellow ironshot Oolite, but it is much softer and more marly than the Paving-stone bed. Hence it is favorable for development, and few fossil-bearing rocks in the English Oolites work better. The fossils are in good spathic condition for the most part, but there is some variety in this, as also in the matrix, due probably to slight differences of position and possibly of horizon. As regards the name *Sowerbyi*-bed, since none but the initiated can pretend to know what the "true *Sowerbyi*" is like, it is difficult to say whether it occurs here. Mr. S. S. Buckman, if I remember rightly, once told me that it was very scarce. The most characteristic Ammonites of this bed, and indeed of this horizon throughout North Dorset, are those allied to *Am. concavus*, which we must regard as a near relative of *Am. Murchisonæ*. As far as my experience goes, if the "true *Sowerbyi*" has any resemblance to Sowerby's figure in the 'Mineral Conchology,' that form is far more common in the so-called *Sauzei*-bed of Osborne than in the so-called *Sowerbyi*-bed of Bradford Abbas. It may be that in that part of Germany whence Oppel, and after him Waagen came, the true *Sowerbyi* is plentiful in the bed that bears its name, but such is not the case with us. Now, there can be no doubt, as I hope has been already made clear, that the zone in question corresponds to a portion at least of the Norman "Mâlière;" indeed, this is shown to be the case by Waagen himself. Yet I cannot find in the works of M. Eugène Deslongchamps any evidence that the "true *Sowerbyi*" is in any way characteristic of the Norman "Mâlière," though *Am. concavus* is held to be so. As this is the most important bed for Gasteropoda hitherto discovered in the English Oolites, there should be as little obscurity as possible about its position in the geological scale, and we should endeavour, for the Dorsetshire District, to seek our parallels in Normandy rather than in Wurtemberg. Since it is recognised as the *Sowerbyi*-bed, let it be known that in this country the recognition can only be granted on the *lucus a non lucendo* principle, and that the name *concavus*-bed or beds would with us be far more appropriate.

It may interest some of the readers of the Palæontographical Society to know that this remarkable bed, which was sedulously worked for many years by the late Professor Buckman, attracted the attention of the late Dr. Wright. In the year 1856 the results of his impressions on North Dorset were published in the 'Quarterly Journal of the Geological Society' (vol. xiii, p. 309). Dr. Wright was then disposed to correlate the Bradford Abbas fossil-bed with the Frocester Cephalopoda-bed, or zone of *Am. radians*, and he named it the Cephalopoda-bed, which for him formed a portion of the Lias. Hence Professor Buckman complained



that he saw in some collections fossils from his own fossil-bed at Bradford Abbas marked "Lias." Now, if we regard the "Marnes Infra-oolithiques" of Eugène Deslongchamps as forming a portion of the Lias, then the *concausus*- or *Sowerbyi*-bed of Bradford Abbas will fall into that category; but in this case the greater part of the Inferior Oolite in England will have to be relegated to the Lias, a proposition which must not be entertained for a moment. At the same time it cannot be too often insisted on that our *Sowerbyi*-bed forms no portion of the Oolite of Bayeux. It distinctly belongs to the *Lower Division* of the Inferior Oolite, and constitutes its highest member. Hence we shall find that the Gasteropoda differ considerably from those of the Bayeux Oolite, and that is one reason why so many species hitherto unknown are found there. It follows from this that Dr. Wright was equally mistaken when, rushing from one extreme to the other, he afterwards placed the Bradford Abbas fossil-bed in the *Humphriesianus*-zone ('Quart. Journ. Geol. Soc.,' vol xv).

Amongst the Gasteropoda of the "fossil-bed" there are several species of *Purpurina*, some decidedly new. *Spinigera* is well represented, and that too by some new and curious forms. The species of *Alaria* are not without resemblance to those described by Schlumberger from the East of France. As regards *Cerithium*, the prevailing species in the beds of Bayeux are here represented by related rather than by identical forms, whilst the rarer and less widely distributed species would appear to be altogether different. Much the same may be said with regard to the other genera, and if we seek for a complete antithesis in England, it may be sought in the almost equally rich shell-bed ( $P_1$ ) at Burton Bradstock, which contains extremely few species identical with those of the bed now under consideration. The exact equivalents of the "*Sowerbyi*-bed," as known in North Dorset, are by no means clear in the Cotteswolds, nor, for the matter of that, in any other part of England, so far as I am at present aware.

The two thin beds which succeed in the quarry are of but little interest for us. The "rotten-bed," which is so full of *Astarte obliqua*, may possibly be an attenuated representative of the *Humphriesianus*-zone. In point of thickness more than half the quarry belongs to the *Parkinsoni*-zone. Here we would fain institute a comparison with the same zone as developed at Burton Bradstock. The conditions are different, however, and we can hardly see in the marl-bed with *T. Morieri* the exact equivalents of  $P_1$ . Nevertheless, both here and in the white limestone above, the species of Gasteropoda which do occur are mostly identical with those noted from the same horizon on the coast.

HALFWAY-HOUSE QUARRY is rather nearer to Bradford Abbas than to Sherborne, and to some extent partakes of its nature and characteristics. I do not know of many Gasteropoda having been obtained from here. The usual grey calciferous grit called the "Dew-bed" forms the base, and above this occur some four feet of

massive and partly ironshot limestone, full of keeled Ammonites, many of which belong to the *concavus* group. *Terebratula perovalis*, var. *ampla*, is characteristic of the higher block. Mr. Whidborne has obtained a few good Gasteropoda from here, which appear to me to have been procured from the *concavus*-bed or beds. These then belong to the Lower Division.

A few inches of rather fossiliferous brash, with many *Astarte obliqua*, separates the *concavus*-beds from the undoubted *Parkinsoni*-beds. Very large specimens of the var. *Dorsetensis* are obtained from the lowest beds, which also have yielded a few Gasteropoda. A great physical change comes on here in the thickening of the Upper Limestones above the main fossil-bed, the total thickness of limestone exceeding thirty feet, which is very different to anything hitherto noted, where the usual thickness of the Inferior Oolite Limestone has not much exceeded twelve feet.

LOUSE HILL.—This place is near Halfway House. I have not been to it myself, but there is said to be a thin ferruginous bed which yields fossils of the *Humphriesianus*-zone. I have a great many specimens of *Pleurotomaria* from here, but few if any are fit for figuring.

SHERBORNE.—Two and a half miles east of Halfway House. There are several quarries, especially towards the north-west of the town, where the Inferior Oolite has been worked. Immense numbers of Ammonites have been obtained from these, and from excavations for houses. More than one zone is well developed, but as I have few if any Gasteropoda from here, a detailed description would be superfluous. The fossils show that there is a rich development of the *Humphriesianus*-zone, but the bulk of the limestones, nearly forty feet thick altogether, are in the *Parkinsoni*-zone, which has yielded lately a splendid specimen of *Megalosaurus Bucklandi*, von Meyer. Speaking generally, however, the neighbourhood of Sherborne, especially Osborne and Milborne Wick, is famous for a good development of the *Humphriesianus*-zone. Indeed, this immediate neighbourhood is the only one in the Dorset-Somerset District where beds of that age occur to any extent.

OSBORNE (*Frogden Quarry*).—If Burton Bradstock gives us the Gasteropoda of the *Parkinsoni*-zone to perfection, if Bradford Abbas is still more famous for the Gasteropoda of the *Murchisonæ*- and *Sowerbyi*-zones, in this quarry we possess the best example which England affords of the beds of Bayeux—the “oölith ferrugineuse,” which is mainly characterised by *Stephanoceras* and *Sphaeroceras*—in other words, the zone of *Am. Humphriesianus*. The traveller from Normandy by the route we have taken might well wonder what had become of D’Orbigny’s typical Bajocian, but here it is at last.

Beginning from the base as usual, we note that the Lower Division of the Inferior Oolite is not represented by fossils in this quarry, though it is probably represented by some of the massive series of calciferous grits, which extend for a

## Profile No. 5.—FROGDEN QUARRY.

		Parkinsoni-zone, continued.
UPPER DIVISION.	Parkinsoni-zone.	3' 0" Pale fissile Limestones of the <i>Parkinsoni</i> -zone, with few fossils.
		Alternations of brownish Limestone and brash, <i>Rhynch. spinosa</i> , &c.
		5' 6" Lower down, small var. of <i>T. sphaeroidalis</i> , peculiar form of <i>Cosmoceras</i> , &c.
	Humphriesianus-zone.	The CADOMENSIS-bed. GASTEROPODA.
		1' 0" H <sub>3</sub> <i>Ter. sphaeroidalis</i> abundant in the lower part.
LOWER DIVISION.		4' 0" H <sub>2</sub> Ironshot Oolites in strong blocks, especially characterised by large specimens of <i>Am. Humphriesianus</i> and <i>Blagdeni</i> . A few <b>Gasteropoda</b> .
		The <i>Sauzei</i> -bed, or 0' 6" H <sub>1</sub> Marl with green grains. GASTEROPODA.
		1' 0" Solid block of bluish-grey Limestone.
	15' 0" Total.	Calceiferous grits, with fossils of the Lower Division.

considerable depth below the worked stone. The top of this series would be the "solid block of bluish-grey limestone," on which the so-called *Sauzei*-bed reposes. This *Sauzei*-bed is one of the most remarkable fossil-beds in Dorsetshire, and has mixed relations, no doubt, both with the Lower and Upper Divisions of the Inferior Oolite, though in drawing the line we must concede it to the Upper Division. This is another case of a misnomer, as far as Frogden Quarry is concerned, since it contains hardly any specimens of *Sphæroceras Sauzei*. Most of the Ammonites are keeled, which at first sight would militate against its being placed in the Upper Division. Again, what I conceive to be the "true *Sowerbyi*," or something very near to it, is far from being uncommon in this bed. All we can say, therefore, is that probably somewhere or other *Sphæroceras Sauzei* does characterise a bed which is about the same horizon, and contains a somewhat similar facies to this one.

The Gasteropoda in the *Sauzei*-bed are abundant and well preserved, and the matrix is on the whole favorable for extraction, being a soft, whitish limestone with green (? glauconitic) grains passing into the ironshot Oolite of the bed above. For the sake of distinction, and as indicating the position assigned to it, I call this bed  $H_1$ . The Gasteropoda seem to present forms that are intermediate between the "*Sowerbyi*-bed" of Bradford Abbas and the more recognised species of the *Humphriesianus*-zone. It is very rich in *Pleurotomariæ*, another characteristic which it shares with the beds of Bayeux; in some other respects it seems to possess features of its own.

At Milborne Wick the *Sauzei*-bed ( $H_1$ ) seems more or less blended with the main *Humphriesianus*-bed ( $H_2$ ), nor do I know of the distinctive development of this sub-stage anywhere else throughout the country.

The main mass of the *Humphriesianus*-zone ( $H_2$ ) calls for few remarks. It is not particularly rich in Gasteropoda as far as my experience goes. Probably some of the specimens from  $H_1$  in an ironshot matrix ought rather to be referred here.

The remaining sub-stage of the *Humphriesianus*-zone ( $H_3$ ) deserves a little attention on our part. It is a thin bed of brown ironshot Oolite, mostly of a peculiar character, which lies just above a bed very full of *Terebratula sphæroidalis*. There is a most curious admixture of Ammonites. *Am. Martinsii* is common high up, and several species of *Cosmoceras* and *Oppelia* abound. *Cosmoceras Niortensis* and allied forms are especially numerous, and there occurs the curious little *Am. cadomensis*, which may well give its name to the bed, simply as a local name. Probably neither *Am. Humphriesianus*, nor *Am. Parkinsoni* properly so called occurs here, and it is evidently debateable ground between the two zones. It contains numerous species of *Astarte*, and many Gasteropoda. This horizon, or sub-stage, cannot be very far from that of  $P_1$  at Burton Bradstock. However, this must be lower in the geological scale, though not much. The Gasteropoda occur for the

most part in a brown-coloured rock of very meagre touch, more or less charged with ironshot ova which have a great tendency to fly upon fracture, leaving cavities which give the rock a somewhat carious aspect. This bed has greater resemblance to the usual Dundry matrix than any fossiliferous bed with which I am acquainted in Dorsetshire, and its Gasteropoda are in a peculiar condition in many respects. A very characteristic fossil is *Pseudomelania coarctata* or *turris*, and this fossil shows the fine spiral lines in many cases to great perfection. This likewise is almost the only bed known to me in England where the wavy colour bands of *Pseudomelania* are preserved to any great extent, as in the Normandy beds. The species of Gasteropoda for the most part have strong affinities with those of  $H_1$  and  $H_2$ , yet with certain differences which deserve to be recorded.

In order to show the degree of analogy, not to say of similarity, which exists between the remarkable exposure at Osborne and the "Oolithe ferrugineuse" of Normandy, I give an abstract of Eugène Deslongchamps' remarks with reference to its development in the Department of Calvados.<sup>1</sup> He observes that this formation, never more than two mètres in thickness, forms the base of what is for him the Inferior Oolite in the greater part of the Department. It is composed of a yellowish or greyish limestone, sometimes more or less siliceous, and contains a quantity of ironshot (ferruginous) Oolites which give it altogether a peculiar aspect. It is besides remarkable for the enormous quantity of Cephalopods, Gasteropods, and Bivalves which it contains. *It is possible to distinguish in most cases three beds.*

The lowest of these is a kind of conglomerate or rather nodular bed, which contains remanié fossils from the upper part of the "Marnes Infra-oolithiques," which, as we have already seen, corresponds in the main to the Lower Division of the Inferior Oolite. Hence in Normandy there is a break between the Lower and Upper Division, and this break is still more marked in the greater part of the Dorset District; since, in most places, only a doubtful fragment of the *Humphriesianus*-beds intervenes between the Lower Division and the *Parkinsoni*-zone. It may be a matter of doubt how far the lowest bed of the "Oolithe ferrugineuse" corresponds to the so-called *Sauzei*-bed of Osborne, except that it seems to contain a considerable mixture of Ammonites (*Am. Sowerbyi* amongst the number) and a crowd of Gasteropods, amongst others great *Pleurotomarias* so characteristic of the true "Oolithe ferrugineuse."

The second and thickest bed, says M. Deslongchamps, is the true ferruginous Oolite, the hardness of which is usually considerable, and which is pierced by small ironshot Oolites. This formation, the richest of all in fossils, appears to be characterised by *Am. Humphriesianus*, which here acquires a great size. We can scarcely fail to recognise in this the main mass of ironshot Oolite at Osborne ( $H_2$ ),

<sup>1</sup> Op. cit., p. 105.

which is enormously rich in large Cephalopods, though not quite so good for Gasteropoda as the top and bottom beds of the series.

In the Department of Calvados there is a third bed where the ferruginous Oolites become scarce and less well defined. This is characterised by the abundance of *Am. Niortensis* and *Am. Parkinsoni interruptus*, by large varieties of *Pleurotomaria mutabilis*, by *Pl. bessina* and *Pl. scalaris*, and by "*Turbo*" *duplicatus*. Specimens of *Terebratula sphaeroidalis* are more abundant than in the second bed, and *Ter. Phillipsii* may be noted. This description probably fits better with our *Cadomensis*-bed ( $H_3$ ) than either of the other two with their presumed equivalents. The abundance of the peculiar group of *Cosmoceras* indicated by *Am. Niortensis* and *Am. Parkinsoni interruptus* is very suggestive, since this is exactly what we find in  $H_3$  at Osborne. Just as coming events cast their shadows before, so did these precursors of the grand army of *Cosmoceras* prepare the way for the reign of *Am. Parkinsoni* which was shortly to set in.

MILBORN WICK.—This is a roadside exposure, one and three quarter miles north-north-east of Frogden Quarry, where a peculiar phase of the *Humphriesianus*-zone presents itself. About nine feet of rock is exposed, of which the lower three feet are simply calciferous grits (Dew-beds). The "fossil-bed" is about eighteen inches thick, and consists for the most part of a softish white limestone, not unlike the marl with green grains at Osborne. In the upper part are numerous species of *Sphaeroceras*, whilst in the lower part *Am. Humphriesianus* and *Am. Braikenridgii* are not uncommon. *Ter. sphaeroidalis* occurs in the upper part of the fossil-bed. But few Gasteropoda are quoted from here.

*Development of the HUMPHRIESIANUS-zone in Dorset-Somerset.*—A line drawn from near the town of Sherborne in a north-easterly direction to Milborn Wick (Somersetshire) is about three miles in length, and this line coincides with the principal development of these beds in No. 1 District, a development by far the most important in England, though the zone is very well represented at Dundry. Henceforth, as we pass northwards into Somersetshire, the character of No. 1 District undergoes considerable modification.

CORTON DOWN QUARRY.—Between three and four miles due north of Sherborne. The Lower Division is again well represented here, since many specimens of *Am. Murchisonæ* are quoted. No traces of the *Humphriesianus*-zone were observed by me.

Beyond this the exposures are lacking in interest from our point of view until we arrive in the neighbourhood of CASTLE CARY. To the south-east, east, and north-east of this town are three exposures in the Inferior Oolite, which have yielded a fair number of Gasteropoda. As this is a district but little known, the following particulars may be interesting.

WOOLSTON QUARRY.—Seven miles north by east of Sherborne, and three and a half miles south-east of Castle Cary. About seventeen feet of limestone are worked in this quarry, the whole of which is probably in the *Parkinsoni*-zone. It is noteworthy that the Cephalopod facies hitherto so characteristic of No. 1 District here begins to fail us, and immense quantities of Brachiopoda characterise the beds. As the same facies is still better shown in Grove Quarries, together with probably a more complete section, I will at once proceed to their description.

GROVE QUARRIES (see *Profile*, p. 52).—One and three quarter miles east-south-east of Castle Cary. The South Quarry is nearer to Shotwell Farm than to Grove Farm. The face is not so well weathered, but here, as in the other quarry and also at Woolstone, the fossils are mainly obtained on fissure surfaces. The stone itself will not work so as to admit of the fossils being extracted along the partings, like the stone of Bradford Abbas and elsewhere. Hence, only those specimens which weather out are obtained. This peculiarity would seem to hold good throughout the same horizon in No. 2 District likewise.

This particular quarry has the advantage over the others that it seems to afford a tolerably complete section of the Inferior Oolite Limestone at this point. The basal bed, only a few inches thick, is most probably in the Lower Division resting directly on the sands. For palæontological purposes, therefore, everything outside the *Parkinsoni*-zone is atrophied in this immediate neighbourhood. The brown limestones in thick blocks, measuring about nine feet, constitute the most interesting feature, and if these beds require a name we might call them the Trigonia Grits. The rare presence of *Am. Parkinsoni* at the base is quite sufficient to make us feel safe as to the geological position. Roughly speaking, we may represent this fine mass of fossiliferous rock as being on the horizon of  $P_1$  of the coast-section, and as the representative of the Upper Trigonia Grit of the Cotteswolds, which it does to a certain extent prefigure. It is, however, richer in Gasteropoda than the Upper Trigonia Grit and thus helps to maintain the character of the Dorset-Somerset District in spite of its poverty in Cephalopoda. In the north quarry, which is more properly speaking Grove Quarry, the Trigonia Grit is about the same thickness (nine feet), and the joint face of these beds was one mass of fossils before the chisels of collectors began to deface the entablature.

The species of Gasteropoda are clearly those which distinguish the lower beds of the *Parkinsoni*-zone throughout the district, and have certain affinities with some of those of the *Humphriesianus*-zone, but hardly any with the Gasteropoda of the Lower Division such as are obtained in abundance at Bradford Abbas. Owing to the rough nature of the matrix the specimens cannot be placed in the first rank as to condition. Varieties of *Cerithium sub-scalariforme* and the so-called *C. contortum* are plentiful. The latter is especially characteristic of this horizon, and may be traced even into the Cotteswolds.

## Profile No. 6.—GROVE OR SHOTWELL QUARRY.

UPPER DIVISION.		Position of the Fuller's Earth.
UPPER DIVISION. { <i>Spinosa</i> -stage, or <i>Parkinsoni</i> -zone. {	10' 0"	Thin-bedded, whitish Limestones, much broken towards the top, with a sprinkling of Brachiopoda, and at base a bed of <i>Terebratula globata</i> .
	9' 0"	Brownish earthy Limestones in large blocks, weathering dark brown. GASTEROPODA. <i>Trigonia</i> , <i>Rhynchonella spinosa</i> throughout. <i>Am. Parkinsoni</i> at base (rare).
	3' 6"	Softer pale-coloured stone. The lowest bed contains <i>R. spinosa</i> and small <i>Stephanoceras</i> .
	0' 6"	Calciferous grit with keeled Ammonites.
23' 0" Total.		? Yeovil Sands.



The upper beds at Woolston, Shotwell, and Grove contain a scattering of Brachiopoda including *Rhynch. spinosa*, and in the two latter there is a distinct *Terebratula*-bed chiefly made up of a variety of *T. globata*. These beds then would seem to prefigure the *Clypeus*-grit; and on this horizon, if anywhere in the Dorset-Somerset District, specimens of *Nerinaea*, which has hitherto failed the collector, should be sought.

PITCOMB ROAD.—Two and a half miles east by north of Castle Cary. This is the last exposure in No. 1 District of beds containing any noteworthy quantity of Gasteropoda. It is a small roadside section. Reposing directly upon soft yellow sand-rock, believed to form part of the "Yeovil Sands," is (1) a calcareous or subcalcareous bed with shells, fourteen inches thick; (2) a rich shell-bed with many Cephalopoda and some Gasteropoda, thirty inches thick; and (3) pale-coloured limestones, of which three or four feet are exposed in the road cutting. After the experiences of Grove and Woolston this is certainly a surprise, since this "fossil-bed" is clearly not in the *Parkinsoni*-zone. The prevailing Ammonites are keeled, and may be on the horizon of those in the *Sowerbyi*-bed at Bradford Abbas. Perhaps we may obtain further evidence.

*Résumé of the North-eastern half of the Dorset-Somerset District.*

One very striking feature is the difficulty of predicating for any given neighbourhood on what horizon the main fossil-bed shall lie. All the zones, except perhaps the *opalinus*-zone, are well represented, and teem with most beautifully preserved Gasteropoda, some in one place and some in another. Consequently this has for years been the favourite hunting-ground of collectors. A very considerable proportion of the Gasteropoda selected for description in the accompanying Memoir are from this division of No. 1 District, and they are on the whole in by far the best state of preservation. Compared with these the Gasteropoda of the remaining districts are disappointing.

*Border region of the Mendips.*

If we allow, for purposes of delimitation, that the prolongation of the Mendip axis shall be considered to divide District No. 1 from District No. 2, yet there is a considerable portion of the Inferior Oolite outcrop on both sides of this axis which contains no shell-beds with Gasteropoda, and with which we need not trouble ourselves. The country from Bruton to Radstock, a distance of twelve miles if measured in an air-line, but more if we trace the edge of the outcrop in the neighbourhood of Frome, will be comprised in this border region. This presents many features of interest to the physical geologist, containing in some

places, and notably near Doultong and Cranmore, under the very shadow of the Mendips, thick beds of freestone of Inferior Oolite age, as also at Old Ford, near Frome. The well-known section at Vallis, where something like fifteen feet of Inferior Oolite rests on the Carboniferous Limestone, seems to show that only beds of the age of the *Clypeus*-grit were deposited upon the old ridge at that spot. Why the vicinity of the old reef should have been unfavorable to the accumulation of shell-beds with Gasteropoda is very difficult to say. But we find in all cases the border regions to be less rich than the central parts of the several districts or basins.

#### DETAILS OF THE COTTESWOLD DISTRICT. (No. 2.)

In a sense strictly topographical the country between Frome and Bath can scarcely be regarded as forming part of the Cotteswold Hills, though, to a certain extent, a physical continuation of that range. The exposures of Inferior Oolite throughout this portion of No. 2 District are neither numerous nor important in a palæontological sense. We have already seen that thick beds of pale-coloured oolitic rock (freestones) on both sides of the Mendips replace the rich shell-beds and ironshot Oolites of No. 1 District. This phase continues for some distance north of Frome. The evidences of Gasteropoda are slight, yet not devoid of interest; there is, however, one great drawback, viz. that most of these fossils are in the condition of casts. The high ground north of Radstock is capped by a sort of plateau of Inferior Oolite, and here the following exposures were examined.

CLAN DOWN.—One and a half miles north-west of Radstock. There are several shallow pits on this down, where the upper beds of the Inferior Oolite have been worked. Of the general development of Inferior Oolite at this spot, and whether there is any representative of the Lower Division, I am ignorant. The unconformity must be considerable, since the Inferior Oolite is represented in the Survey map as resting on Lower Lias; in one pit, where seven feet of beds are exposed, the upper portion consists of a shivery whitish limestone with a variety of *Terebratula globata* scattered about, and containing a shell-bed with *Trigonia* and *Nerinaea* in casts, also *Natica Bajocensis* and a small *Trochus*. Below this is a much harder block of stone. *Nerinaea* occurs in casts, rather numerous at the top, and also in a shell-bed lower down. There is more than one species, but *Nerinaea Guisei* is most probably one of them. As we shall see subsequently, this is a very well-marked horizon in the *Clypeus*-grit, and it is extremely interesting to have obtained proofs of it thus early in our examination of the Cotteswold District. As far as we know at present, this is the most southern locality in England where *Nerinaea* has been found to occur in the Inferior Oolite, and abundantly too, since there are no less than three shell-beds traceable here.

**RED POST QUARRY.**—Due north of Radstock on the Bath road. There are twenty-one feet of beds exposed here, made up of oolitic grains and comminuted shelly matter in small granules. It is pale in colour, but weathers brown, and may be regarded as an inferior freestone. There are a few fossils here and there, and low down occur traces of a *Trigonia*-bed, but the most interesting feature for us is a line of hardish stone, between three and four feet from the top, which contains casts of a *Nerinea* with very complicated folds (*Ptygmatis*). We cannot help contrasting these thick and comparatively unfossiliferous exposures, entirely confined to one zone of the Inferior Oolite, with the dozen feet or so of Burton Bradstock or Bradford Abbas, full of organic remains, and exhibiting, if not the entire formation, yet most excellent representatives of both the Upper and Lower Divisions. There are a few other exposures in this neighbourhood of the same horizon containing *Nerinea*, and notably one at CARNICOT.

**TWERTON HILL.**—We pass over a considerable extent of country without finding much of interest in the Inferior Oolite, until within one and three quarter miles west-south-west of Bath. At the Mission Chapel there are two exposures, one on either side of the road. In that on the east side the Fuller's Earth may be seen atop, and below this about fifteen feet of rough freestone is worked. The upper portion is very white and chalky. About ten feet down the stone becomes firmer, and here occurs a shell-bed in very fine Oolite, which contains *Nerinea Guisei* and another species, also an *Alaria* and numerous *Trigonia*, *Ostrea*, &c.

On the opposite side of the road is a disused quarry, where the face of rock is somewhat limited. Towards the top is a shell-bed with *Nerinea* and corals, and hereabouts may be noted *Ceromya striata*, *Pholadomya Heraulti*, and several species of *Myacites*, some in a vertical position. This deposit rather reminds us of the *Pholadomya*-grit, a term given by Lycett to the series of beds usually known as the *Clypeus*-grit. The point to observe here is that, although there are fifteen feet of rock, only the very highest series of beds are exposed, and these contain *Nerinea*, like their equivalents near Radstock.

**MIDFORD.**—Three miles south-south-east of Bath. Owing to a cutting on the high road we obtain here a complete section of the Inferior Oolite Limestone—the first that we have seen in No. 2 District. There is probably about forty feet of rock, and the whole of this mass belongs to the Upper Division. Indeed, we may go closer than this, and regard it as mainly, if not wholly, within the *Parkinsoni*-zone, since *Ammonites Martinsii* occurs quite in the lower stage, which appears to me to represent the Upper Trigonia Grit of Stroud and Cheltenham. In that case the Inferior Oolite Limestone of this section would be the equivalent of the entire Upper, and part of the Lower, Ragstones of the Cotteswolds proper. There are but few Gasteropoda from here, and I should scarcely have ventured to say so much about it but for the fact that the *Midford Sands*, which underlie this limestone,

have been taken to represent the Sands of the Gloucestershire Cephalopoda-bed. In default of fossil evidence this is a dangerous assumption, since the whole of the Lower Division of the Inferior Oolite is absent as a limestone, and may possibly be represented by the upper portion of these same Midford Sands.

FRESHFORD.—This is a section in the Avon valley about four miles south-south-east of Bath. Only a portion of the Upper Division of the Inferior Oolite is seen here. It contains a *Clypeus*-grit Fauna, and there are traces of the horizon of *Nerinea Guisei*.

The sections above detailed, from Clan Down to Freshford inclusive, may be taken to give an idea of the general development of the Inferior Oolite in the little known country between the Mendips and the Avon valley. Whether the Lower Division is developed at all in that area is unknown to me. We should certainly expect to find it on the escarpment, where possibly it exists without being quarried. But opposite the escarpment, and about eight miles nearly due west of Twerton Hill, occurs the remarkable outlier of

DUNDY HILL.—This place is one of the most classic in the annals of the Inferior Oolite, since so many of Sowerby's types come from here; and it has also furnished the Bristol Museum with the greater part of the material so well elucidated by my lamented friend, Tawney, in the 'Dundry Gasteropoda.' I have already pointed out the anomalous character of this exposure of Inferior Oolite. It might be almost regarded as constituting a district by itself, so curiously does it combine the characters of No. 1 District with those of No. 2. Still, although it lies north of the Mendips, we must hold that its affinities with the Inferior Oolite of Dorset and Normandy far exceed any resemblance which it possesses to the main mass of the Cotteswold Oolite. Judging from the fossils, it is probable that more than one horizon has contributed its quota to this assemblage; though perhaps the highest beds are so loaded with massive *Thamnastræa* as not to have afforded much space for the accumulation of shells. In the present condition of the available exposures it is by no means easy to construct an intelligible section of the Inferior Oolite in this remarkable hill. Instead of going into the question of horizons we must be content to take the fossils as we find them in the various museums—at least for the present.

#### *The Cotteswold Hills.*

The range of the Cotteswolds may be said to commence north of the deep valley of the Avon, whence it continues in an almost unbroken escarpment for many miles. There are no exposures of any importance, as far as I am aware, until we reach the neighbourhood of Little Sodbury, some ten or twelve miles from Bath. This circumstance probably arises from the facility with which Carboniferous





THE  
PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

VOLUME FOR 1886.

L O N D O N :

MDCCCLXXXVII.





A MONOGRAPH

ON THE

# INFERIOR OOLITE AMMONITES

OF

THE BRITISH ISLANDS.

BY

S. S. BUCKMAN, F.G.S.

PART I.

PAGES 1—24. PLATES I—VI.

LONDON :

PRINTED FOR THE PALEONTOGRAPHICAL SOCIETY.

1887.

PRINTED BY  
ADLARD AND SON, BARTHOLOMEW CLOSE.

# A MONOGRAPH

## ON THE

### INFERIOR OOLITE AMMONITES.

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It was with great hesitation that I offered to prepare a Monograph on the Inferior Oolite Ammonites. I was, however, strenuously urged to do so by Dr. Davidson,<sup>1</sup> to whom I am greatly indebted for every possible kindness and encouragement, which I most gladly acknowledge. When I considered the vast amount of study and labour that such a monograph would entail, and compared the limited amount of time at my disposal owing to the cares of business, I was for deferring my work or giving to others with more leisure the opportunity to undertake the task. Dr. Davidson, however, pointed out to me the advantage that I had of a very large amount of material collected during many years by my father and myself, and also that I was acquainted with the different localities and horizons from which the various species came, by having myself obtained and developed so large a number of them. This, however, only applies to a small area of the Inferior Oolite in the South-west of England, and I must rely on the kindness of correspondents to enable me to figure those species which occur in this formation in other districts. It is, however, pretty well known that the Inferior Oolite in the South-west of England contains a far larger proportion of Ammonites than any other district except perhaps Dundry. With the Dundry beds I am not actually acquainted, but the Ammonites that I have seen from them are certainly in every way similar to ours in the South-west.

As far as possible I intend to figure the best procurable examples, and also enough specimens to show the different ages and variations of each species, so that it may without doubt be easily recognised. It sometimes happens to be a very hard matter to show in a plate the particular characters which dis-

<sup>1</sup> Since the above was written, I unfortunately have to say "the late Dr. Davidson." I cannot take a better opportunity to express my sorrow, and to acknowledge the unfailing kindness which I always received from him.

tinguish a certain species from any others, but I shall endeavour to point them out as clearly as possible in my descriptions. I would also draw particular attention to the study of the suture lines of Ammonites, which has, in many cases, been very much neglected, and I hope to be able to give an accurate delineation of those of each species which will come under my notice.

#### GEOLOGICAL CHARACTERS.

The first point to be considered is the vertical extent of those beds of the Ammonites which I propose to describe, that is to say, the limits of the Inferior Oolite, its commencement and its close. And it is more especially with the former of these questions—whether certain beds belong to the Inferior Oolite, or should be classed as a continuation of the Upper Lias—that we have to deal, since the different development of these, so to speak, intermediate beds in different districts has given occasion for a large amount of writing and a great difference of opinion, and has been the frequent cause of confusion. The subdivision of formations into zones and subzones will most probably help us to more thoroughly elucidate the matter, and leave us with a single point to determine, namely, whether a particular zone shall belong to the Lias or Inferior Oolite. Upon this matter it may be as well to give shortly the opinions of a few authorities. For instance, Dr. Oppel, who studied the whole of the Jurassic rocks in England, France, and Germany, and who was probably the first to separate the various formations into zones, gives in his work,<sup>1</sup> page 305, the *Torulosus*-bett as the lowest bed belonging to the Inferior Oolite, and underneath he ends the Upper Lias with the *Jurensis*-bett; see also his opinion, page 299. Between the *Murchisonæ* and *Jurensis* beds he places two others, the *Trigonia navis* bed and the *Torulosus* bed. These two are now generally united under the name of “*Opalinum*-zone.” Therefore Dr. Oppel begins the Inferior Oolite with the “*Opalinum*-zone.” The next point to determine is what Dr. Oppel calls the *Torulosus* bed, and on this point we have his opinion on page 296 of the same work, where he gives a section of Frocester Hill, and there places the upper portion of the Ammonite bed in the zone of *Torulosus* and the lower portion in the zone of *Jurensis*, making the division between Lias and Oolite in the middle. So far we have the opinion of one authority as to the proper starting point of the Inferior Oolite in Gloucestershire, and of course according to his decision we should know the beginning of the Inferior Oolite in other parts to be with the zone of *Torulosus*, provided we can determine the position of the said zone.

<sup>1</sup> Oppel, ‘Die Juraformation Englands, Frankreichs und des Südwestlichen Deutschlands,’ 1856—1858.

Prof. Quenstedt in his 'Cephalopoden,' page 12, would seem to make the division between Lias and Oolite between the bed with Jurensis and that of Opalinus. At any rate his "Schwarzer Jura" ends with the Jurensis bed and his "Brauner Jura" begins with that of Opalinus.

My father, the late Prof. Buckman, wrote several papers on the Oolites, and more especially the Inferior Oolite of Gloucestershire and Dorset, with both of which counties a long residence had made him well acquainted. Whilst in the former county, and even afterwards, he wrote several pamphlets to combat Dr. Wright's upward extension of the Upper Lias, so as to include the sands and the Frocester Hill Cephalopoda bed, because my father contended that not only the Cephalopoda bed, but also the sands below, should be included in the Inferior Oolite as is shown by a section of Frocester Hill (Buckman, 'Journal Geological Society,' 1857, page 103), and he also contended that these sands were in reality on the same horizon as the Pea Grit (Pisolite) beds of other parts of the Cotswolds, and differed from them only by their chemical composition having produced sand instead of stone.

This view as to the sands and Pisolite beds we find in 1857 expressed as follows. "What, then, is here meant by the *equivalents of the sand*? My present opinion is, that the sands of Frocester are identical in time with the mixed pisolitic beds of the Cheltenham district, and that the iron-shot sands of the Dundry Hill and Somerset sections are also of the same period; the pisolitic conditions prevailed in one part of the Oolite sea, and sandy ones in another; and hence the difference of the fauna."<sup>1</sup> After my father had removed to Dorset and had the opportunity of studying the Inferior Oolite there, we find the same view expressed in a paper read to the Somersetshire Archæological and Natural History Society on the Cephalopoda bed, &c., in 1874, viz. (page 7): "The so-called 'Lias or Oolite Sands' underlying the Bradford Oolitic stone are really the representatives of the lower members of the Inferior Oolite of Gloucestershire, at least for 100 feet of their thickness," and we have the Dorset Cephalopoda bed defined as the representative of the Rubbly Oolite at the top of Leckhampton Hill and Cold Comfort, or the equivalent of the Gryphite and Trigonina Grits (see same page). For further remarks on this subject I must refer the reader to another paper on "The so-called Midford Sands," 'Quarterly Journal Geological Society,' 1879, by my father. Now, if these opinions as to the correlation of the Midford or Yeovil Sands with the Pisolite beds of Cheltenham district be correct, those sands naturally belong to the Inferior Oolite as my father contended, and he would therefore commence the Inferior Oolite with the Murchisonæ-zone; but for this he had to suppose the existence in Dorset of two portions of sands separated by a Cephalopoda bed, the

<sup>1</sup> "The Oolitic Rocks of Gloucestershire and North Wilts," by Prof. Buckman, 'Quart. Journ. Geological Society,' vol. xiv, 1857, p. 106.

upper portion of these sands being equivalent to the Pisolite and the lower portion to the sands and marls of the Upper Lias which occur in Gloucestershire. I shall give some further opinions on this view presently.

In reading the descriptions of Brachiopoda by M. E. Deslongschamps, 1862, we find that he places between the Oolite and the Lias certain beds which he calls Infra-Oolitic marls. In these Infra-Oolitic marls he places the Opalinum-, Murchisonæ-, and Sowerbyi-zones (see pages 213, 209, &c.), and he would seem to wish to begin the Inferior Oolite proper with the zone of Am. Sauzei. Mr. Hudleston once suggested the proposal of two large divisions for the Inferior Oolite, the one called the Harpoceras-zone to end with the Sowerbyi-bed, because Ammonites belonging to the division Harpoceras are the characteristic fossils, the other to contain the Sauzei-, Humphriesianum-, and Parkinsoni-zones and to be called the Stephanoceras-zone, or probably I would rather suggest, Stephanoceratites-zone. This, however, is a digression, and does not help us to determine the lowest zone of the Inferior Oolite, except that it shows how a division could be made. Deslongschamps has recognised this, and proposed to make as it were a small intermediate formation, as if to combine the various views of different authors, under the name Infra-Oolitic marls. It must, however, be noticed that he ends the Lias with the Jurense-zone.

Dr. Wright, in his 'Monograph on the Lias Ammonites,' at page 148 (Palæontographical Society, vol. xxxiii, 1879) brings in the Opalinum-zone as the highest zone of the Lias; and after describing where it occurs and its characteristics, he says, "From the Haresfield bed I have taken a piece of rock having the impression of *Harpoceras opalinum* on its underside, whilst the block itself contained Inferior Oolite fossils." These words to my mind do not point to any great advantage in making the division between Lias and Oolite at a point where the zones are so intimately connected, unless the majority of authors express a preference for this as the distinguishing point. At the same time it could probably be urged that wherever the distinction were drawn some locality or other would present this difficulty. Dr. Wright has, however, so far carried out his opinion that he has figured and described in his Monograph a number of Ammonites from the Opalinum-zone. Consequently, even if it be determined, that it is advantageous that the Opalinum-zone should belong to the Inferior Oolite, I should find part of my work done by Dr. Wright. It is not improbable, however, that wherever the division between Lias and Oolite may be drawn, I may have some species to describe from the Opalinum-, and perhaps Jurense-zone, so as to be able to connect Dr. Wright's splendid 'Monograph on the Lias Ammonites' with the present work without any break.

Dr. Branco, in 'Der Untere Dogger Deutsch-Lothringens' (page 14), begins his description of the Dogger as follows:—" (1) Die Schichten mit *Harpoceras*

*striatum*. (a) Unterregion: Thone mit *Astarte Voltzii* und *Cerithium armatum* ('Oppel's Zone des Amm. torulosus')."

I have now given the opinions, as far as I have been able to ascertain them, of a few of the authors who have made the Inferior Oolite their study, and it certainly seems that the more usual custom is to divide the Lias from the Oolite at the top of the Jurensen-zone, of course commencing the Inferior Oolite proper with the Opalinum-zone. I now propose to give some few sections of the beds of the Inferior Oolite to try and clear up some of the differences which exist as to their correlation, and I think I shall be able to clearly prove that the Yeovil Sands and the Cotteswold Sands are identical, and that the Inferior Oolite in the South of England, although not very thick, contains good representatives of all the zones into which that formation has been divided in different countries.

The following is a section of the Inferior Oolite showing its relation to the sands below. This section is as it were made up of two portions; the first, from Nos. 1 to 7 inclusive, is taken, with some slight alterations and additions, from my paper read to the Geological Society on the Inferior Oolite Ammonites, 1881, and is the result of my own observations. For the lower part of the section I am indebted to my father's paper on the Cephalopoda bed.<sup>1</sup> This is a very carefully measured section of the sands of Babylon Hill near Yeovil; and, although it is situated about a mile from the quarry which my section represents, yet there is on the top of the hill a quarry (Anbury) which is, stone for stone, the exact counterpart of the Bradford Abbas East Hill Quarry, indeed I do not know any species which the one possesses foreign to the other, their Fauna and lithological characters being practically identical. For further evidence on this point see my father's paper just quoted, page 3.

*Section of the Inferior Oolite and the Sands at Bradford Abbas, Dorset.*

	Ft.	In.	
{ 1	6	6	White Oolite, rather soft, almost unfossiliferous except in its lower part.
{ 2	0	3	Marl bed, contains <i>Tereb.</i> <i>Morieri</i> , <i>Rhynch.</i> <i>parvula</i> , <i>Wald. carinata</i> .
{ 3	0	6	Bluish stone, contains small <i>Stephanoceras Humphriesianum</i> , <i>Tereb. sphaeroidalis</i> .
{ 4	0	6	Irony stone, contains one or two species of <i>Harpoceras</i> .
{ 5	2	0	Yellowish stone, contains a quantity of Gasteropoda and Ammonites.
{ 6	1	0	Yellowish brown stone, comes out in large slabs.
{ 7	1	2	Very hard blue centred stone, contains many fragments of shells, also <i>Harpoceras Moorei</i> , <i>Lyc.</i>
{ 8	?		A slight break of uncertain amount, but not more than 10 feet.
{ 9	5	0	Fine yellow sands.
{ 10	0	9	Sands with stone, or hardened sandy stone.
{ 11	1	6	Fine yellow sands.
{ 12	1	0	Sands with stone, or hardened sandy stone.
{ 13	10	0	Sands with irregular stone.
{ 14	2	6	Sands with stone, or hardened sandy stone.
{ 15	15	0	Sands with irregular stone.
{ 16	2	0	Stone.
{ 17	5	0	Fine yellow sands.
{ 18	2	9	Irregular masses of stone.
{ 19	4	0	Fine yellow sands.
{ 20	1	6	Two bands of stone.
{ 21	3	6	Fine yellow sands.
{ 22	2	0	Stone.
{ 23	50	0 about.	Sands with occasional layers of stone in the upper part.

<sup>1</sup> "The Cephalopoda Bed and Oolite Sands," by Prof. Buckman, 'Proceedings Somersetshire Archæological Soc.,' vol. xx, 1874.

This section contains the following zones :

- 1 and 2. Parkinsoni-zone.
3. Probably representative of Humphriesianum-zone.
4. Perhaps equivalent to the Sauzei bed at Osborne.
5. Sowerbyi-zone.
6. Murchisonæ-zone.
- 7—23 (7 ?). Jurensæ-zone.

This section and the one of Stroud Hill given below show how remarkable is the difference in thickness between the rocks of the Inferior Oolite at Bradford Abbas and Stroud, but that there is not really so very much difference in the thickness of the Yeovil and the Cotteswold Sands. The Dorset section, however, does not give the full depth of the sands at this point as it could not be exactly ascertained right down to the Lias shales.

These sands are extraordinarily well exposed near Bridport Harbour and at the Cliffs at Burton Bradstock, and are estimated to be upwards of 200 feet thick. Of the Cotteswold district I cannot speak from my own knowledge, but Mr. Witchell gives the depth of the sands at Stroud Hill at about 110 feet, whilst from Dr. Wright's section of Cleve Hill, Gloucestershire, given in his 'Monograph on Lias Ammonites,' page 155, they would appear to be only from 2 to 3 feet thick. It would therefore seem that the depth of these sands varies more between different localities in the Cotteswolds than it does between some parts of the Cotteswolds and Dorset.

The Yeovil Sands are of a more clayey tenacious character and of a darkish blue colour towards the lower part. This may be well observed in a railway cutting between Yeovil and Yeovil Junction. They are not greatly fossiliferous, but I have met with *Harpoceras Moorei* (Lycett) in various places at the top, middle, and lower parts, and *Lytoceras jurensæ* has also been obtained. These fossils always occur in the bands of stone. At Yeovil Junction to the west of the station is a fine quarry from which a considerable number of fossils have been procured, while a few yards farther on in a field is a capital quarry of the Inferior Oolite containing very small representatives of all the zones of that formation, very much thinned out, so that its total depth does not here exceed about 6 feet; a few yards still farther on westwards one comes to the Fuller's Earth Clay.

I here give part of a section of Stroud Hill, which I have taken from the 'Geology of Stroud' (the section faces page 5 of that work), by my friend, Mr. E. Witchell, to whom I am indebted for much information regarding the Cotteswold Hills. Below is his explanation according as I have numbered the beds.



*Section of Stroud Hill (Cotteswolds).*

	Ft.	In.	
0	25	0	Blue marly clay.
1	3	0	Upper bed of Inferior Oolite.
2	8	0	{ Clypeus Grit, <i>Tereb. globata</i> , <i>Clypeus Plottii</i> .
3	4	6	
4	3	0	
5	6	0	Upper coral bed.
6	12	0	Upper Trigonia Grit.
7	10	0	Gryphite Grit.
8	6	0	Upper Freestone.
9	70	0	Oolite Marl.
10	3	0	About. Building Freestone.
11	25	0	Pea Grit, <i>Tereb. plicata</i> , &c.
12	9	0	Lower Limestone in thick beds.
13	6	0	Brown ferruginous beds.
14	110	0	About. Cephalopoda bed.
15	70	0	About. Cotteswold Sands, the lower part occasionally concretionary.
			Upper Lias, bands of blue shale.

A point suggested by a consideration of this section and that of Bradford Abbas Quarry, given at p. 5, is whether the "Dew bed" (No. 7) which I have placed as the top of the Jurense-zone may not in reality be the exact equivalent of the Gloucestershire Cephalopoda bed which is No. 13 in the section of Stroud Hill. It directly underlies the paving bed or Murchisonæ-zone, so that we must suppose that the Opalinum-zone is not represented; but that this is not unusual appears from Dr. Wright's section of Leckhampton Hill, near Cheltenham,<sup>1</sup> in which he places the zone of Murchisonæ directly upon the zone of Jurense, omitting any mention of the Opalinum. At a quarry at East Coker in Somerset, from which the sinistral gasteropods *Cirrus nodosus*, *Leachii*, &c., are obtained, as far as I can make out, the Parkinsoni-zone rests directly on the Murchisonæ-zone, there being not the slightest trace of the intermediate zones or their fossils. When one considers this and the thinness of the Inferior Oolite in Dorset in many other places, one can scarcely wonder at zones being looked upon as fanciful divisions, nor at the statement that all the zonal Ammonites, Parkinsoni, Humphriesianum, Sowerbyi, and Murchisonæ occurred mixed together in a few feet of rock.

Now, as regards the correlation of the two sections: In the Bradford Abbas section, Nos. 1, 2, are in the zone of Parkinsoni, and are probably the equivalent of Nos. 1—5 Stroud section; Nos. 3—5 are probably equivalent to No. 6, and perhaps 7. Whether 8 of the Stroud section should be included it is difficult to say, the Fauna being so dissimilar, or whether it should be included with 9—12 as the equivalent of No. 6 in the Bradford section. No. 7 of the Bradford section seems to me to be very probably the equivalent of No. 13, the Cephalopoda-bed of the Stroud section, and Nos. 9—23 of No. 14. I can see no reason why Nos. 9—23 should be supposed, as my father did, to be of the same age as the Oolite marl and Pea Grit or Nos. 7—12 of the Stroud section, as this puts a bed containing *Harpoceras Moorei*, Lyc. (No. 7 of Bradford Abbas

<sup>1</sup> 'Monograph on the Lias Ammonites,' by Dr. Wright. Palæontographical Society, vol. xxxiii, 1879, pp. 151, 152.

section), up above, or else equivalent to, the Upper Freestone or Oolite marl of the Cotteswolds. Besides this we have some very good evidence showing the identity of the Murchisonæ-zone in Dorset with at any rate the Pea Grit of Gloucestershire, so that there seems no reason for supposing that the Yeovil Sands are of any higher horizon than those of the Cotteswolds, especially as we find an extensive amount of Cotteswold Sands shown in the Stroud section. Our evidence as to the identity of the Murchisonæ bed in Dorset with the Pea Grit and other beds (9—12) in Gloucestershire is founded on the following list of species which occur in both places: *Harp. Murchisonæ*, *Terebratula perovalis*, *Tereb. Etheridgii*, *Tereb. simplex*, *Rhynch. subangulata*, *Rh. subdecorata* (the small kind), *Rh. cynocephala*. I believe that this is the first time that that most characteristic species *Tereb. simplex* has been found outside the Cotteswolds. I possess, however, as many as eight fine large examples of this shell from two quarries in Bradford Abbas and one near Sherborne (Dorset). The first I found were submitted to Dr. Davidson, and were by him identified as undoubtedly belonging to this species.

*Section at Osborne Quarry, near Sherborne, Dorset.*

	Ft.	In.	
Light coloured stone .....	2	0	Parkinsoni-zone.
Soft sandy stone .....	2	0	} Humphriesianum-zone.
Harder stone iron grains .....	3	0	
White marl with green grains .....	0	6	Sauzei-zone.
Hard blue and yellow stone .....	2	0	} Sowerbyi-zone.
Several feet unseen			
Soft yellow sandstone containing <i>Rhynch. ringens</i> at the top of it .....		Uncertain	

*Section at Wyke Quarry, near Halfway House, Sherborne, Dorset.*

	Ft.	In.	
Whitish stone extending up the hill, perhaps .....	20	0	Parkinsoni-zone.
Dark red stone filled with iron .....	0	7	Humphriesianum-zone.
Bluish stone, sometimes yellow with plenty of iron grains.			} Sowerbyi-zone.
<i>Rhynch. ringens</i> found in lower part .....	3	10	
Lighter yellow stone, the lower part hidden, visible .....	2	0	Murchisonæ-zone.

I have here given two sections in the Inferior Oolite which are taken from my paper on "Ammonites," 'Quart. Journ. Geol. Soc.,' vol. xxxvii, p. 588, &c., 1881. They are of Osborne in Dorset, and of Wyke Quarry near Halfway House, Sherborne, and I have reproduced them to show the difference that exists in the beds in Dorset in a little distance, these two quarries being about five miles apart, and also to show their correlation. It seems to me that the section at Osborne must have very much the character of the Oolite of Normandy, while our Bradford Abbas or Wyke sections are different, in fact differing as much from it as they

do from Osborne. This seems to be supported by the fossils, because if we look through d'Orbigny's 'Paléontologie française (Céphalopodes)' we find none of what might be called the fossils peculiar to Bradford Abbas represented; the real fact being that of the species figured by d'Orbigny, probably *Am. Sowerbyi* is the only one which came from the zone of that name, and it is *this* zone which is so fossiliferous at Bradford. *Stephanoceras Humphriesianum* has been found at Bradford in the bed No. 3, but it is rare and generally very poor, so that roughly speaking the Fauna at Bradford Abbas is totally distinct from that at Osborne. There seems, therefore, to be in the south a parallel to the Normandy beds, both in fossils and characters, and also to the Cotteswold beds in fossils, but not in character.

I need scarcely remark on the correlation of the two sections given above, as it seems to be evident from the sections themselves. Practically identical lists of fossils have been obtained from the various beds allocated in each quarry to the same horizons or zones,<sup>1</sup> and these lists of species having been compiled, after particularly observing the exact position from which every species that I collected was taken, I am enabled to definitely assign the zone to which the beds belonged. It is interesting to note the occurrence of *Rhynchonella ringens* in both places. The Osborne and Bradford Abbas' quarries are the types of the two classes of Inferior Oolite rocks to be met with in the south-west. In one class it is the Sowerbyi-zone that preponderates and is most fossiliferous, while in the other it is the Humphriesianum.

One bed of which there seems to be no representative in the south is the Oolite marl. It is in fact a most difficult matter to say with what it should be correlated. It is true that in the south *Terebratula curvifrons* has been found in the Murchisonæ-zone, but it is rather different in shape from the one found in the Oolite marl of the Cotteswolds. At a quarry on Corton Downs in Somerset there is a blue clay with bands of stone in it, much resembling the blue parts of Oolite marl shown at Notgrove Station, Gloucestershire. This clay is quite stiff and some 3—4 feet thick. It contains, however, the usual fossils of the Sowerbyi bed at Bradford Abbas, *Lioceras concavum* (Sow.), *Terebratula Eudesi*, *Rh. Forbesi*, &c., being found there, but we have never seen anything at all like the Fauna of the Oolite marl.

As regards the thickness of the Inferior Oolite rocks in the South of England: They probably at no one place from the zone of Murchisonæ upwards occupy more than 40 feet, although of this we cannot be certain. Just to the north of Sherborne in Dorset the Parkinsoni beds are quarried and expose a thickness

<sup>1</sup> I ought here to explain that the Humphriesianum-zone is fossiliferous both at Osborne and Wyke quarries, and that the list of fossils mentioned refers more particularly to this bed. At Osborne the Sowerbyi-zone has yielded but few fossils, but enough to identify it. Wyke quarry differs from Bradford Abbas in having the Humphriesianum-zone fossiliferous.

of quite 30 feet, and we do not then find either the top or bottom of the zone. It is almost unfossiliferous, but occasionally *Cosmoceras Parkinsoni*, *Perisphinctes Martinsii*, and some Brachiopods are found. The most fossiliferous exposure of the Parkinsoni-zone, as far as Ammonites are concerned is at Halfway House, where the fossils occur in the lower portion, and at Broad Windsor, and Burton Bradstock, Dorset, and Crewkerne Station, Somerset. The deepest development of the Humphriesianum-zone with which I am acquainted is at Osborne, where it is divided into two distinct beds with distinct Faunæ, measuring 5 feet altogether. The upper portion contains *Cosmoceras subfurcatum* (Schloth.) = *Am. niortensis*, d'Orb., *Cosm. Garantianum* (d'Orb.), *Perisph. Davidsoni*, S. Buck., &c. Below the Humphriesianum-zone proper comes the Sauzei bed, which may probably after all be only a subzone of the Humphriesianum. It is 6 inches thick at Osborne. The greatest development of the Sowerbyi-zone is at Halfway House, where it is about 4 feet, and contains a large number of species of the genus *Harpoceras*. We have lastly the Murchisonæ-zone, which attains as much as 4—5 feet at Corton Downs in Somerset.<sup>1</sup> Therefore we have, putting these maxima developments of the Inferior Oolite all together, a thickness of not much less than 50 feet. Were we able to see a complete opening near Sherborne we should expect the beds there to be best developed in every way; while, as they extend westwards, they gradually thin out until at Stoford they are only about 6 feet thick; and at East Coker, because some are absent they are not more than 3—4 feet. We do not know, however, how much of the upper part of the Parkinsoni-zone, there represented, may have been denuded.

#### PALEONTOLOGY.

Before commencing any description of the various species we must consider their classification. The genus "Ammonites" having become unwieldy, and not being in accordance with the usages of modern science, we find that a large number of new genera have been proposed, with the intention of taking its place. The late Dr. Wright in his 'Monograph on the Lias Ammonites,' devoted a considerable amount of space to a very full and excellent description of all the systems of classification that had been proposed. In fact he gives us an account of the classification, not only of the Ammonites, but of the Cephalopods in general. With the Ammonites he commences with the first efforts at subdivision, viz. L. von Buch's, into families, continuing with Prof. Quenstedt's additions, a whole *résumé* of d'Orbigny's twenty-one sections, and ending with a complete account of the

<sup>1</sup> The Opalinum-zone is shown near Broad Windsor and at Burton Bradstock, Dorset, and near Haselbury, Somerset, and the amount exposed varies from 2—5 feet in thickness. *Lioceras opalinum*, and *Terebratula infra-oolithica* are the typical fossils.

various systems of classification proposed by Hyatt, Neumayr, Waagen, Favre, and others, he gives us that system which he himself thought it best to adopt. It is quite unnecessary for me to go over all this ground again. The general principle and the general mode of subdivision are now almost unanimously agreed upon and recognised. I intend to introduce new genera and to restrict many of those now in use; and I shall as occasion requires give my views concerning them. During the last few years the introduction of new genera, to partially take the place of the large subdivisions that one finds, for instance, in Dr. Wright's Monograph, has been frequent. Thus, part of what Dr. Wright included under Harpoceras is now put into Hammatoceras, and this genus again has been lately divided into that and Sonninia. These new genera arise out of the necessities of the case. It having been once agreed that a division of "Ammonites" was necessary, limits cannot directly be set to such division. The introduction of Arietites, Harpoceras, and Stephanoceras was a step in advance, but each included very diverse forms.

It will thus be seen that there has been a constant tendency to more and more subdivision, and I venture to advance still farther in this direction. Exception may probably be taken by some persons to the number of genera into which I shall propose to divide the Ammonites in this Monograph, but I would draw attention to other sciences, entomology, botany, &c., and would point out the large number of genera which they contain, and ask why we should not in palæontology proceed on the same lines, viz. make a genus for the reception of a group of a larger or smaller number of species having certain points and characters *in common*, distinguishing them from other groups. This will be more clearly brought out in the definition of each genus, which I shall give. It is now several years since Hyatt attempted to divide the Ammonites into what may be called small genera. His system was at the time too great a stride in advance, and also too faulty, to find acceptance. Since then we have had the division of Ammonites into genera brought into ordinary use, but the genera used were much more comprehensive than Hyatt's, including, in fact, not only several of his genera, but two or three or more of his families in one. Now, however, we are returning towards the direction taken by Hyatt, and in fact we use, on account of their priority, a number of the generic names that he proposed.

I have found that the importance of accurate examination of the various suture lines was not to be overlooked, and that instead of the sutures varying in specimens of the same species, as had been asserted, they were generally very constant in form, not only in a species, but for a genus. I found, however, that owing to the usually very perfect preservation of the Inferior Oolite Ammonites in the South of England, and to collectors rejecting specimens not having the test, I had often great difficulty in making out the suture line as I could wish.

It is very singular that, so far as I know, no Aptychus has been found in the

South of England, either *in situ* or separate. This is very much to be wondered at and regretted, as there is little doubt that a knowledge of the *Aptychus* would give us help and information in the matter of subdivision.

I commence this Monograph with the study of the *Falciferi* or part of the genus *Harpoceras* of Waagen, and I here give a short account of the history and origin of some of the principal genera.

It was in 1867 that Alpheus Hyatt published in the 'Bulletin of the Museum of Comparative Zoölogy at Harvard College,' in Cambridge, U.S.A., a comprehensive system of families and genera for the Ammonites contained in that Museum. Unfortunately, however, his paper is unaccompanied by any plates, and his descriptions are rather short and terse, the paper chiefly being made up of references to various authors and to the localities whence the specimens came.

Hyatt does not seem to have dealt with anything besides Ammonites from the Lias, to which formation almost all his genera belong, only one species in his paper being from the Inferior Oolite proper, namely, *Lioceras concavum*, although *Lioceras opalinum*, *Grammoceras radians*, &c., may be said to belong to it. This paper, however, is most important to us in the study of the Inferior Oolite Ammonites. It enables us to assign, if possible, the correct generic appellations to the various species, because it was one of the early efforts made towards a very complete subdivision of the genus "Ammonites," and because Hyatt went so much farther in that direction than his contemporaries. Let us now examine a few of his genera, and, as one in which we shall be soon interested, let us take *Lioceras*. In this genus Hyatt seems both to myself and others to have united several very different groups of species. For instance, Haug,<sup>1</sup> who has written a capital pamphlet on the Harpoceratidæ, has retained under the subgenus *Lioceras*, *L. concavum*, *L. opalinum*, *L. elegans* of Hyatt's paper, but he has placed *Am. lythensis* in a group of its own and *Am. discoides* in the group of *Am. falcifer*. We must, therefore, as Hyatt has not given us a species as his type of the genus, take the larger number which evidently comprise one group, and we consequently select *Lioceras opalinum* as the type, followed by *Lioceras elegans*, &c. It may be objected that, as Hyatt placed *Am. lythensis* first, he intended it for his type; but the *Opalinum* group are in a majority, and have been usually taken as the types of *Lioceras* to the exclusion of other forms. We wish, therefore, to amend Hyatt's genus by restricting it to the group of which *Lioceras opalinum* is the type.

As to the genus *Grammoceras*, which also contains species of diverse character, *Grammoceras striatulum* seems to be usually taken as the type with *Gram. radians*, *Am. aalensis* and *Am. costula* undoubtedly form a distinct group, while *Am.*

<sup>1</sup> E. Haug, "Beiträge zu einer Monographie der Ammoniten-Gattung Harpoceras," 'Neues Jahrbuch für Mineralogie, &c.,' Beil.-Bd. iii.

*serpentinus* is by Haug placed in the genus *Hildoceras*. In the Inferior Oolite there are some species which very closely approach the type of this genus, but may have to be separated. The only other genus of Hyatt's that we need remark upon is that of *Hammatoceras* (see Hyatt, page 88), mentioned again on page 98 and spelt *Ammatoceras*. Under this genus, the type of which is *Ham. insigne*, have been placed by some authors a number of Inferior Oolite species such as *Sowerbyi*, *adicrum*, *patella*, &c. These species have been generally placed in the genus *Harpoceras*, which was created by Waagen to include the *Falciferi* and *Insignes*. Dr. Wright, too, in his *Lias Monograph* has adhered to the plan of keeping the *Insignes* in the genus *Harpoceras*. Previously, however, Neumayr<sup>1</sup> in a very interesting paper, had expressed his opinion that it was advisable to keep *Hammatoceras* for the group of *Am. insignis*, and this plan has been followed by the majority of Continental authors. Bayle, however, in the same year in his 'Explication de la Carte géologique de la France,' proposed the genus *Waagenia* for a species allied to *Am. Sowerbyi*. The name *Waagenia*, however, having just previously been used by Neumayr, was changed to *Sonninia* (see 'Bullet. Société géol. France,' vol. vii, series 3, page 92, 1878-79).

In 1869 Waagen proposed the name *Harpoceras* as a generic name for all those *Ammonites* with falciform sculpture and distinct keel, and cited as his examples of this genus, *Harpoceras Actæon*, *Masseanum*, and *arietiforme*, which belong to the *Falciferi* of the *Lias*; and he proceeds to say that next come the *Insignes*, the *Falciferi* of the Brown *Jura* with keeled body chamber, *Harp. opalinum*, *Edouardi-anum*, *hecticum*, *Henrici*, *canaliculatum*, *trimarginatum*, and lastly *Harp. Zio*.<sup>2</sup> Hyatt had, however, a year or two previously more minutely divided a large portion of *Ammonites*,<sup>3</sup> and had dealt with part of these very fossils which Waagen here mentions. He had divided what Waagen wished to call *Harpoceras*, as far as the *Lias* is concerned, into four families—*Phymatoidæ*, *Cycloceratidæ*, *Discoceratidæ*, and *Hildoceratidæ*; and into eight genera—*Phymatoceras*, *Hammatoceras*, *Tropidoceras*, *Ophioceras*, *Pelecoceras*, *Hildoceras*, *Grammoceras*, *Leioceras*. These divisions were, however, thought too fine, and we consequently find that Waagen's genus *Harpoceras* was more generally used. Tate and Blake<sup>4</sup> use it throughout their work, and Dr. Wright throughout the whole of his *Monograph* in the entire form in which Waagen proposed it. Now, however, that smaller divisions are found

<sup>1</sup> Neumayr, "Ueber unvermittelt auftretende Cephalopodentypen," &c., 'Jahrbuch der K. k. geologischen Reichsanstalt,' Band xxviii, 1878, pp. 37-80 (see footnote, p. 67). I would also call attention to another important paper of Neumayr's in 'Zeitschrift der deutschen geologischen Gesellschaft,' Band xxvii, 1875, where the generic grouping and classification of *Ammonites* is most thoroughly worked out.

<sup>2</sup> Waagen. 'Die Formenreihe des *Ammonites subradiatus*,' p. 250 (72).

<sup>3</sup> Hyatt, 'Bulletin of the Museum of Comparative Zoology of Harvard College,' 1867, pp. 71-102.

<sup>4</sup> 'The Yorkshire Lias,' 1876.

desirable and Hyatt's genera are being adopted in consequence of priority, it becomes very hard to say to what to apply the genus *Harpoceras*. For instance, in the genus *Tropidoceras*, Hyatt had placed *Am. Actæon* and *Am. Masseanus*, which Waagen had specially mentioned, and *Am. opalinus* in the genus *Lioceras*. We could then scarcely use *Harpoceras* as the generic name for some of the remainder, because if we pursue the mode of division that we have sketched out we should confine the genus within limits never intended by the author who proposed it for "all Ammonites having a falciform sculpture and distinct keel," and who showed by his list of synonyms<sup>1</sup> the wide application he intended for it.

Haug, in his pamphlet on 'Harpoceras,' makes three genera—*Harpoceras*, *Hammatoceras*, and *Hildoceras*, for what Waagen intended as *Harpoceras*, and he treats as subgenera of these *Tropidoceras*, *Cycloceras*, *Sonninia*, &c. Since we intend to treat these latter as genera, this plan will not help us. We suppose, however, that *Harpoceras* must not be rejected, but it is difficult to know how best to apply it.

Neumayr<sup>3</sup> has divided the subfamily "Ammonites" into four sections, viz. *Arcestdæ*, *Tropiditæ*, *Lytoceratidæ*, *Ægoceratidæ*. The section *Ægoceratidæ* he divided into three subsections, viz. *Ægoceratinæ*, containing *Ægoceras* and *Arietites*; *Harpoceratinæ*, containing *Harpoceras*, *Oppelia*, *Haploceras*; *Stephanoceratinæ*, containing *Stephanoceras*, *Cosmoceras*, *Ancyloceras*, *Perisphinctes*, &c.

Douvillé<sup>4</sup> has proposed to unite *Arietites* and *Harpoceras* into a tribe *Harpoceratinæ*; and *Oppelia*, *Lissoceras*(=*Haploceras*) and *Neumayria* into *Lissoceratinæ*; and then these two, *Lissoceratinæ* and *Harpoceratinæ*, to "form a subfamily *Harpoceratidæ*." I have given considerable time to the classification of these groups, and I venture to suggest that the following method more nearly represents the affinities of the various forms. It will be noticed that I have removed *Amaltheus* from the *Arcestdæ*, as I consider that its general shape, sutures, and structure bring it into closer relationship with *Harpoceras* and *Oppelia* forms.

*Family*—AMMONITIDÆ, to contain subfamily *Ammonites* (i.e. what was previously included in the old genus), and also *Hamites*, *Baculites*, &c.

*Subfamily*—AMMONITES, to contain tribes<sup>4</sup> *Arcestdæ*, *Tropiditæ*, *Lytoceratidæ*, *Ægoceratidæ*.

*Tribe*—ÆGOCERATIDÆ, to contain subtribes *Ægoceratinæ*,<sup>5</sup> *Harpoceratinæ*.

<sup>1</sup> Waagen, before quoted, p. 245 (67).

<sup>2</sup> 'Zeitschrift d. deutschen geol. Gesellschaft,' p. 854—942 (see p. 905), 1875.

<sup>3</sup> Zone of *Am. Sowerbyi*, 'Bulletin Soc. géol. France,' ser. 3, vol. 13 p. 14.

<sup>4</sup> These divisions, as well as the one above (*Ammonitidæ*), are called by Wright and Neumayr families, but this seems confusing, since they are two different classes of divisions, and by Douvillé subfamilies. This latter term seems in contradiction to the rule given by Strickland ('Scientific Writings, Zoological Nomenclature,' p. 394) that families should end in *idæ* and subfamilies in *inæ*.

<sup>5</sup> This includes Neumayr's *Stephanoceratinæ*. See further on.



*Subtribe*—HARPOCERATINÆ, to contain generic groups Arietidæ, Amaltheoidæ, Hammatoceratidæ,<sup>1</sup> Lissoceratidæ.

*Generic group*—HAMMATOCERATIDÆ, to contain generic subgroups Hildoceratinæ, Hammatoceratinæ, &c.

The generic subgroup Hildoceratinæ would include such genera as Lioceras, Ludwigia, &c., whilst Hammatoceratinæ would include Hammatoceras, Sonninia, &c., but I propose not to give the definition of the subgeneric divisions of the Hammatoceratidæ at present, as new forms are constantly cropping up and new characters discovered so that it is at present difficult to say what should be included in them.

<sup>1</sup> Hyatt's names Phymatoidæ, Hildoceratidæ, would only express probably what is equal to the subgroups Hildoceratinæ, Hammatoceratinæ, and cannot therefore be used here. This name (Hammatoceratidæ) is not open to that objection, but at the same time expresses the same as Waagen's genus Harpoceras.

**Tribe—ÆGOCERATIDÆ, Neumayr.**SUBTRIBE—HARPOCERATINÆ, *Neumayr*.Generic group—HAMMATOCERATIDÆ, *Buckman*.Generic subgroup—HILDOCERATINÆ, *Buckman*.Genus—LUDWIGIA, *Bayle*, 1878.(Type—LUDWIGIA MURCHISONÆ, *Sowerby*, sp.)

*Definition*.—Variable, sometimes much compressed; strongly marked reflexed bifurcating ribs, primary large, especially conspicuous in youth, and sometimes almost developing spines. Ventral area plain, without ribbing, somewhat flattened, keel variable. Mouth border with an elongated lappet on the lateral area, and very slightly produced on ventral area. Inner margin always concave. Umbilicus open, the inclusion generally half the whorl. Suture lines very simple, not numerous, having a well-defined space between each succeeding suture. Siphonal saddle divided by a somewhat rudimentary accessory lobe, lateral saddle scarcely divided by any such lobe. Inferior lateral lobe considerably smaller than superior lateral. Three small auxiliary lobes.

*Remarks*.—This genus does not contain many species, and is hard to define on account of its variability. The most constant characters are the suture lines and the ribs.<sup>1</sup> It will be seen that the suture line<sup>2</sup> enables us to distinguish this genus from *Lioceras*, being more simple, farther apart from one another, possessing only a small accessory lobe in the siphonal and scarcely one in the lateral saddle, which lobes are always well developed in *Lioceras*. The suture line in *Ludwigia* is also less branched, and the saddles proportionately deeper than in *Lioceras*. The umbilicus in *Ludwigia* is also proportionately larger and more open than in *Lioceras*, and does not increase so irregularly when the body-chamber is present.

The genus *Ludwigia* was founded by *Bayle* in 1878 in his 'Explication de la Carte géologique de la France,' and he places in this genus the following Ammonites, viz. *L. aalensis*, *costula*, *opalina*, *mactra*, *exarata*, *Sinon*, and *Murchisonæ*,

<sup>1</sup> It should be especially noticed that, whilst in *Ludwigia* the secondary ribs are well developed, yet the primary are as large or larger than the secondary. On the other hand *Lioceras* has, practically, no primary ribs. The secondary ribs unite more or less about the middle of the side and disappear into lines of growth, or at the most very small ribs which decrease in size as they near the inner margin. This of course does not apply to *Lioceras opalinum* and others, which are merely striated.

<sup>2</sup> See Plate II, fig. 5.

from among which he subsequently<sup>1</sup> chose *L. Murchisonæ* to be the type of his genus. Unfortunately, however, his figure of *L. Murchisonæ* 'Explic. Carte géol. France,' plate lxxv, fig. 1, cannot possibly be considered as a typical specimen of Sowerby's *species*. It is a variation, and a well-marked variation. I have carefully examined Sowerby's type specimen of *L. Murchisonæ*, which is in the Natural History Museum of South Kensington, and compared it with specimens of my own, which I have taken there. Bayle's figure shows a much more finely ribbed specimen with smaller umbilicus, and is a sufficiently distinct variation to require a name. It is too, unfortunately, the variety of *L. Murchisonæ* that most nearly connects that species with the genus *Lioceras*. Further particulars I shall give under the description of *Ludwigia Murchisonæ*. It only remains for me now to say that to retain the generic name *Ludwigia* for a class of species having in common characteristics different from any others, I think it necessary to slightly amend Bayle's genus making the type of Sowerby's species the type of the genus. I paid another visit to the South Kensington Museum on purpose to examine the suture line of Sowerby's original specimen of *L. Murchisonæ*, and I found it to possess a more rudimentary accessory lobe dividing the siphonal saddle, and a rather thinner and longer superior lateral lobe than the specimen figured by Bayle, besides the other differences mentioned above. As these features are characteristic of the genus, I am anxious to amend Bayle's genus in the way I have stated.

LUDWIGIA MURCHISONÆ (*Sowerby*). Plates I; II, figs. 1—5; III, figs. 1—3.

1829	AMMONITES MURCHISONÆ,	<i>Sow.</i>	Min. Conch, pl. 550.
1830	—	—	<i>Zieten.</i> Verstein. Württem., pl. 6, fig. 4 only.
1845	—	—	<i>d'Orb.</i> Ter. Juras., pl. 120, fig. 3 only.
1856	—	—	<i>Oppel.</i> Juraformation, p. 368, No. 18.
1881	HARPOCERAS	—	<i>S. Buck.</i> Quart. Journ. Geol. Soc., vol. xxxvii, p. 603.
1885	HILDOCERAS	—	<i>Haug.</i> Neues Jahrbuch für Mineral., p. 686.

LUDWIGIA MURCHISONÆ, var. OBTUSA (*Quenstedt*). Plate III, figs. 4, 5.

1830	AMMONITES MURCHISONÆ,	<i>Zieten.</i>	Verstein. Württemb., pl. 6, figs. 2 a—e.
1846	—	—	OBTUSUS, <i>Quenstedt.</i> Ceph., pl. 7, fig. 12.
1858	—	—	— <i>Quenstedt.</i> Jura, pl. 46, fig. 5 only.
1884	LUDWIGIA HAUGI,	<i>Douvillé.</i>	Bull. Soc. géol. France, sér. 3, vol. xiii, p. 26.
1885	HILDOCERAS MURCHISONÆ	and HAUGI.	<i>Haug.</i> Neues Jahrbuch für Mineral., Beil.-Band. iii, p. 686.

<sup>1</sup> 'Bulletin Société géologique de France,' sér. iii, p. 91, vol. vii, January, 1879.

LUDWIGIA MURCHISONÆ, var. *BAYLII*, *S. Buckman*. Plate III, figs. 6, 7.

1878 LUDWIGIA MURCHISONÆ, *Bayle*. Explication Carte géol. France, pl. 85, fig. 1 only. (Without further detail I am uncertain about the other three figures.)

Discoid, carinated, whorls somewhat compressed, ornamented in the young stage with reflexed, bifurcating, rounded ribs, of which the primary are rather coarse. Ribs becoming smaller, and finally losing themselves in lines of growth in adult age. Ventral area without ribs, somewhat flattened, with a distinct rounded keel, not so conspicuous on body-chamber. Inner margin concave, inclusion about half the whorl. Mouth border simple, with lateral elongated lappets, and not produced to a point on ventral area.

The variety *L. obtusa* has much the same characters, but the primary ribs are coarser, producing spines in the young stage; the whorls are thicker, narrower, and more quadrangular, the centre is deeper.

The variety *L. Baylii* is like the typical form in general, but has very fine ribs, a smaller centre, and is somewhat thinner.

*Ludwigia Murchisonæ* is a somewhat variable species. What might be called the middle form was figured by Sowerby, and is consequently the type of the species on each side of which stand these varieties, the one coarser ribbed and thicker, the other finer ribbed and thinner. Quenstedt was the first to give a second or varietal name to *L. Murchisonæ*, when he described as *Ammonites Murchisonæ obtusus* the specimen figured in his 'Cephalopoden,' pl. vii, fig. 12, and again in his 'Jura,' pl. xlv, fig. 5. (It should, however, be observed that his *Am. Murchisonæ acutus* on this plate has no connection with the true *L. Murchisonæ*, but belongs to the genus *Lioceras*, being my *Lioc. bradfordense* to be described presently.) It is this *Am. Murchisonæ obtusus* which Douvillé raised to specific rank under the name *Ludwigia Haugi*. But Herr Haug himself, in his pamphlet on 'Harpoceras,' page 687, thinks that it is merely a variety, and not a species. In this opinion I quite concur, and since this form has long been known as a variety of *Am. Murchisonæ* under the name of *obtus*, I have thought it advisable to retain this name. If, however, it had been raised to specific rank, it might probably have been preferable to have retained Douvillé's name of *Haugi*. I have also thought it advisable that the opposite variety of *L. Murchisonæ* should be distinguished, and I have consequently proposed the varietal name *Baylii*, because of the capital figure of this form given by Bayle in the reference quoted at the heading. It will be found that there is a very slight variation in the suture lines of these

three forms, that of *L. obtusa* being the simplest. On Plate II, fig. 5, is a drawing of the suture line of Sowerby's original specimen of this species, made expressly for comparison with that of *Lioceras*. It will be noticed that the lobes are somewhat long and narrow and the saddles rather deep. A small accessory lobe divides the siphonal saddle, while the superior lateral may be said to be quite undivided. The inferior lateral lobe is very much smaller than the superior; and it should be observed that the sutures are apart from each other, hardly anywhere overlapping. Though this perhaps can scarcely be treated as a generic difference, yet it is more the rule in *Ludwigia* and the exception in *Lioceras*.

This species occurs in the zone of the same name. Good typical examples of it are uncommon in the South of England, and the variety *L. Baylii* is the rarest of the three forms. They are generally met with in a very poor state of preservation, and in fact all the good specimens with which I am at present acquainted came from Bradford Abbas, where it occurs in a bed of light brown, somewhat soft stone called the Paving Bed, from the fact that it can be taken up in large layers or slabs and hardens on exposure, when it can be used for flooring. The zone of *Murchisonæ* is met with in many places, viz. Sherborne, Bradford Abbas, Halfway House (Compton), Beaminster, Burton Bradstock, &c., in Dorset; Haselbury, Misterton, Stoford, Corton Downs, &c., in Somerset, from most of which places specimens of either the typical or varietal forms have been obtained. Dr. Wright quotes the species from Cleve, Frocester, and Leckhampton Hills in Gloucestershire. Sowerby's type specimen came from Scotland.

Plate I represents a fine typical example of this species in very perfect preservation. Plate II, figs. 1, 2, represent the original specimen named and figured by Sowerby and reproduced here (side and front views instead of three quarters front) for reference and comparison. Fig. 5 represents the suture line of this specimen, and is the typical suture line of the genus *Ludwigia*. Figs. 3, 4, represent a young shell of this species showing its open umbilicus in youth. On Plate III, figs. 1 and 2, is represented a medium-aged specimen in very good preservation, and of the size usually found. It is figured to show the transition from ribs to lines of growth, and also the bifurcating, reflexed ribs better than the other specimens. Fig. 3 is given to show the termination of the body-chamber, and is the only example at present under my notice. The lateral lappet of the termination is not complete and some other parts of the specimen are somewhat poorly preserved. Figs. 4, 5, show the characters of the variety *L. obtusa* with its coarse, knotted ribs, and its quadrangular section. The keel of this specimen is rather badly preserved and, perhaps, is more prominent. Figs. 6, 7, show the variety *L. Baylii* and its different aspect from the others. I have a larger specimen showing the characteristics of this variety (which becomes

square with a less prominent keel as it gets larger), but it is too poor to figure. I hope to be enabled to figure better specimens of both these varieties of *L. Murchisonæ* another time.

LUDWIGIA CORNU, *S. Buckman*. Plate IV, figs. 1—4.

1881 AMMONITES SUBRADIATUS, *J. Buckman* (non Sowerby). Quart. Journ. Geol. Soc., vol. xxxvii, p. 61, fig. 2.

1881 HARPOCERAS CORNU, *S. Buckman*. Quart. Journ. Geol. Soc., vol. xxxvii, p. 605.

1885 HILDOCERAS (LUDWIGIA) CORNU, *E. Haug*. Neues Jahrbuch für Mineralogie, &c., Beil.-Bd. iii, p. 687, tab. 12, fig. 11.

Discoid, much compressed, carinated, whorls flattened, ornamented with well-marked reflexed bifurcating ribs. Ventral area plain, slightly sloping towards a fairly prominent sharp keel. Inner margin concave. Inclusion variable, about  $\frac{3}{4}$  to  $\frac{7}{8}$  of whorl; centre shallow, regularly coiled, with numerous rather coarse ribs. Termination of body-chamber has long lateral lappets (most probably not increasing in breadth at the end), and is produced and pointed on ventral area.

This species is only variable to a very slight extent, the specimens with the larger umbilicus having rather coarser ornamentation than the others. From the preceding species, this one differs considerably, being more compressed, with a sharper, more angular keel. Its suture lines are the same as those of *Ludwigia Murchisonæ*; if anything, more simple. This seems to have been a small species as I have never seen a specimen much larger than those figured in the plate. It is not uncommon with more or less of the terminal lappets preserved, and on account of them was always formerly quoted from the Bradford Abbas district under the name of *Ammonites subradiatus*, Sow. (to which species it bears no other resemblance), until I corrected the mistake and gave it the name of "*cornu*" on account of these lappets. This species occurs in the Sowerbyi-zone at Bradford Abbas and other quarries in the neighbourhood where the zone is exposed, and it is not uncommon. It is associated with *Lioceras concavum* (Sow.), and several other species of that group, and is probably not unfrequently confounded with the common *L. concavum*.

Plate IV, figs. 1—4, show the two forms of this species, and give a back and front view. The keel of fig. 2 is hardly prominent enough, owing to absence of test in many places. The flatness of the side view of fig. 1 seems to me not quite sufficiently brought out.

## HILDOCERATINÆ.

*Genus*—LIOCERAS, Hyatt, 1867.

(*Type*—LIOCERAS OPALINUM, Reinecke, sp.)

*Definition*.—Compressed, discoidal, divisible into two groups, one, the more typical, subcarinated, the other acutely and distinctly carinated. Umbilicus in general small, the inner whorls in some species being almost entirely occluded. Inner margin always concave. Termination, so far as known, has a double bend, sometimes produced and pointed on ventral area.<sup>1</sup> Body-chamber just half a whorl. In young state ornamented with falciform, more or less bifurcating ribs, in adult with plain falciform ribs<sup>2</sup> inconspicuous on inner area or else the whole perfectly smooth, with merely lines of growth. The inner margin of body-chamber always recedes from the regular line of coil of the centre, giving to the umbilicus of complete specimens a sub-oval appearance. As the shell grows and the chambers are formed, the inner margin advances towards its regular place nearer the centre. (This peculiarity exists in some genera of other groups of Inferior Oolite Ammonites and requires to be well understood.) The suture line is peculiar and very constant. The general characters are that the siphonal lobe is rather short. The siphonal saddle is divided into two parts by a well-marked accessory lobe, the inner part being invariably the deeper. The principal lateral lobe is broadly stemmed, digitated, and with three terminal branches which partly penetrate the same lobe of the preceding suture line and almost touch the preceding saddles on both sides of it. The lateral saddle is divided by an accessory lobe. The inferior lateral lobe is smaller than, but very similar to, the principal one; there are four auxiliary lobes and three saddles, the first lobe being well developed.

*Remarks*.—This genus, as I have pointed out, is divisible into two portions, the one almost without a distinct keel, the other with a very distinct, prominent keel, leaving the ventral area flat and almost furrowed. The principal lateral lobe of this latter class has not three such distinct terminal branches, but I am unable to say

<sup>1</sup> The young specimens of some species of this genus have lateral lappets. *Lioceras opalinum* also possesses these lappets at maturity.

<sup>2</sup> The character of the ribs in adult *Lioceras* is shown on Plates V and VI. The inner area is smooth and depressed, the secondary ribs on the outer area are few but conspicuous, and appear like a succession of notches. Still the type of the genus, *Lioceras opalinum*, has really no ribs, but merely very numerous lines of growth, which are sometimes fasciated (as Dr. Wright calls it), producing *false* irregular ribs.

whether this character may be constant and peculiar to this class. As at present constituted, this genus is one of the most important of the Hildoceratinæ in the Inferior Oolite. Of the type of this genus, *Lioceras opalinum*, Dr. Wright has already given excellent figures and an exhaustive description;<sup>1</sup> he claims it and its zone as belonging to the Upper Lias, although he admits on page 464 that the Germans hold different views. I have referred to this subject before (see the Introduction) and stated the information and opinions I could obtain. There is little doubt that in Gloucestershire the Opalinum-zone is more allied to the Upper Lias, whilst in Dorset the sequence of strata is not sufficiently shown. We must, however, look at general characters, and not at the peculiarity of a particular district like Gloucestershire, when settling the question.

*Special Distinctive Characteristics.*—These may be shortly stated as, when young, evolute; in middle age, involute; adult becoming less involute proportionally; inner margin concave; differing especially from *Ludwigia* in absence of ribs on the inner area and in having the siphonal saddle divided by a good-sized accessory lobe, leaving the interior portion deeper than the exterior; the lateral saddle also divided by an accessory lobe, the inferior lateral lobe nearly as long as the superior lateral, the first auxiliary lobe nearly as large as the inferior lateral; all these lobes touching those preceding them, and one suture line seeming to overlap another. Suture line generally much incised. Four auxiliary lobes.

*LIOCERAS BRADFORDENSE*, *S. Buckm.* Plate IV, figs. 5—8; Plate V.

1881 *HARPOCERAS MURCHISONÆ*, var. *BRADFORDIENSE*, *S. Buckman.* Quart. Journ. Geol. Soc., p. 604.

1858 *AMMONITES MURCHISONÆ ACUTUS*, *Quenstedt.* Der Jura, pl. 46, fig. 4 only, not 5.

Shell discoidal, compressed, subcarinated, whorls compressed, very little convex, ornamented with a number of small, plain, curved, but not prominent costæ, sometimes bifurcated. Body-chamber smooth, with outer margin almost rounded in adult specimens, and about half a whorl in length. Inner margin concave. Inclusion quite three quarters of a whorl in half-grown specimens, less in very young forms, and decreasing to half a whorl in full-grown ones. Aperture from sagittate to suboblong. Mouth-border plain, produced on lateral and ventral areas, rounded on the first and pointed on the second. Umbilicus always showing portions of each of the inner whorls, like so many small steps. The suture line of

<sup>1</sup> 'The Lias Ammonites,' Wright, Palæont. Soc., vol. xxxviii, 1884, Plate LXXX, figs. 6—8, pp. 463—466.



this species answers in general to the description given of that of the genus. It differs in no important points. The accessory lobe dividing the siphonal saddle is not so large as in *Lioc. opalinum*.

This species occupies a most extraordinary position. As its age varies it so nearly approaches in shape either to *Lioceras concavum* or else to *Ludwigia Murchisonæ*, that until we had the evidence of the suture line it was a constant source of perplexity to decide its true position. *Ludwigia Murchisonæ* is also such a variable form that it seemed quite possible to include this species, occurring as it does in the same bed, as one of its varieties. This is the view that I took in 1881, in the reference quoted above, and is also the view taken by Prof. Quenstedt in his 'Jura,' plate xlv. It has no doubt been figured in other places under the name of *Am. Murchisonæ*; for so closely does our species sometimes simulate the varieties of the latter that unless we had the additional evidence of the suture line we should often be unable to identify figures. Again, this species is not at all easy to separate from specimens of *Lioceras concavum* in middle age. There can, however, be no difficulty with the adult forms, because the umbilicus of *Li. bradfordense* is then large and open, while that of *Li. concavum* keeps to its small hollow form. The best distinction between middle-aged *Li. bradfordense* and *Li. concavum* is that in the umbilicus of the former a small portion of each of the inner whorls is exposed, forming small steps and showing the ribs, while in *Li. concavum* this is not the case. Did we, however, not possess the large adult forms of this species, it would seem scarcely sufficient to make a distinction between it and *Li. concavum*. The most peculiar character about this species is its approach to the form of *Ludwigia Murchisonæ* when it is rather more than half grown, and to *Li. concavum* when younger. In fact, it possesses the shape of *Ludwigia* except from young to middle age, while it has the suture line of *Lioceras*. It should be noticed that Quenstedt's figure, referred to as a synonym of this species, gives the suture line very clearly, figures 4 and 5, plate xlv ('Der Jura'), illustrating the difference in the suture line of *Ludwigia* and *Lioceras*. We can note that in *Ludwigia* the suture lines are far removed from one another, are rather simpler, and possess only a very rudimentary accessory lobe to divide the siphonal saddle, whereas we see the suture lines of *Lioceras* more or less overlapping, much closer together, and possessing a well-developed accessory lobe in the middle of the siphonal saddle.

*Lioceras bradfordense* is not a common shell, and on account of the nature of the beds it is seldom well preserved. It belongs to the Murchisonæ-zone, and in Dorset it has been obtained from Bradford Abbas and other quarries near. From near Beaminster the larger adult examples mostly come, and it is here more frequent. From East Coker in Somerset I have seen very large examples, but they are generally fractured in all directions.

The position of *Lioceras bradfordense* is somewhat peculiar, it being the one species of *Lioceras* which approaches in some things nearest to *Ludwigia*. Though occurring in the Murchisonæ-zone, or midway as it were between *Lioceras opalinum* in the zone of that name, and *Li. concavum* in the Sowerbyi-zone, it is not the connecting link, as one would expect, between *Li. opalinum* and *Li. concavum*. Bigger than either, with larger umbilicus, it has not quite the true *Lioceras* form.. Nor again, is this species, in spite of the resemblances I have pointed out, any intermediate form between *Lud. Murchisonæ* and *Li. concavum*. The latter species is not derived through *Li. bradfordense* from *Lud. Murchisonæ* as I have heard it stated, but is clearly a descendant of *Li. opalinum*. When I first applied the name *bradfordense* I was uncertain if Quenstedt's *Am. Murchisonæ acutus* was the same. Still, the name *acutus* having been used for an Ammonite by Sowerby and again by Tate for a Harpoceras, I could not have retained it in any case. Having then, in 1881, more or less established the name *bradfordense* I do not think it at all advisable to alter it, although it is now in the genus *Lioceras*.

On Plate IV, figs. 5, 6, is shown a medium-sized specimen of this species with the termination. At this size the species may be said to be in all respects of the true *Lioceras* form, and, with its broad flat sides and small deep centre, could not, I think, be easily confounded with any specimen of *L. Murchisonæ*. In fact, I have generally found it more difficult to distinguish poorly-preserved specimens of this size from *Li. concavum*. Fig. 7 gives the side view of a younger and smaller shell. Its front view is proportionately much the same as Fig. 6. Fig. 8 shows two suture lines taken from the large specimen figured on Plate V and placed here for convenience. Plate V, figs. 1, 2, show a larger, but hardly full-grown example, with the body-chamber, occupying just half a whorl, present. (The specimen has just an indication of termination.) Fig. 1 shows the receding of the inner margin mentioned before, which in this species varies in amount with the age. Fig. 2 shows the small amount of keel present even where the test is on, and the almost rounded character of the ventral area on the body-chamber.



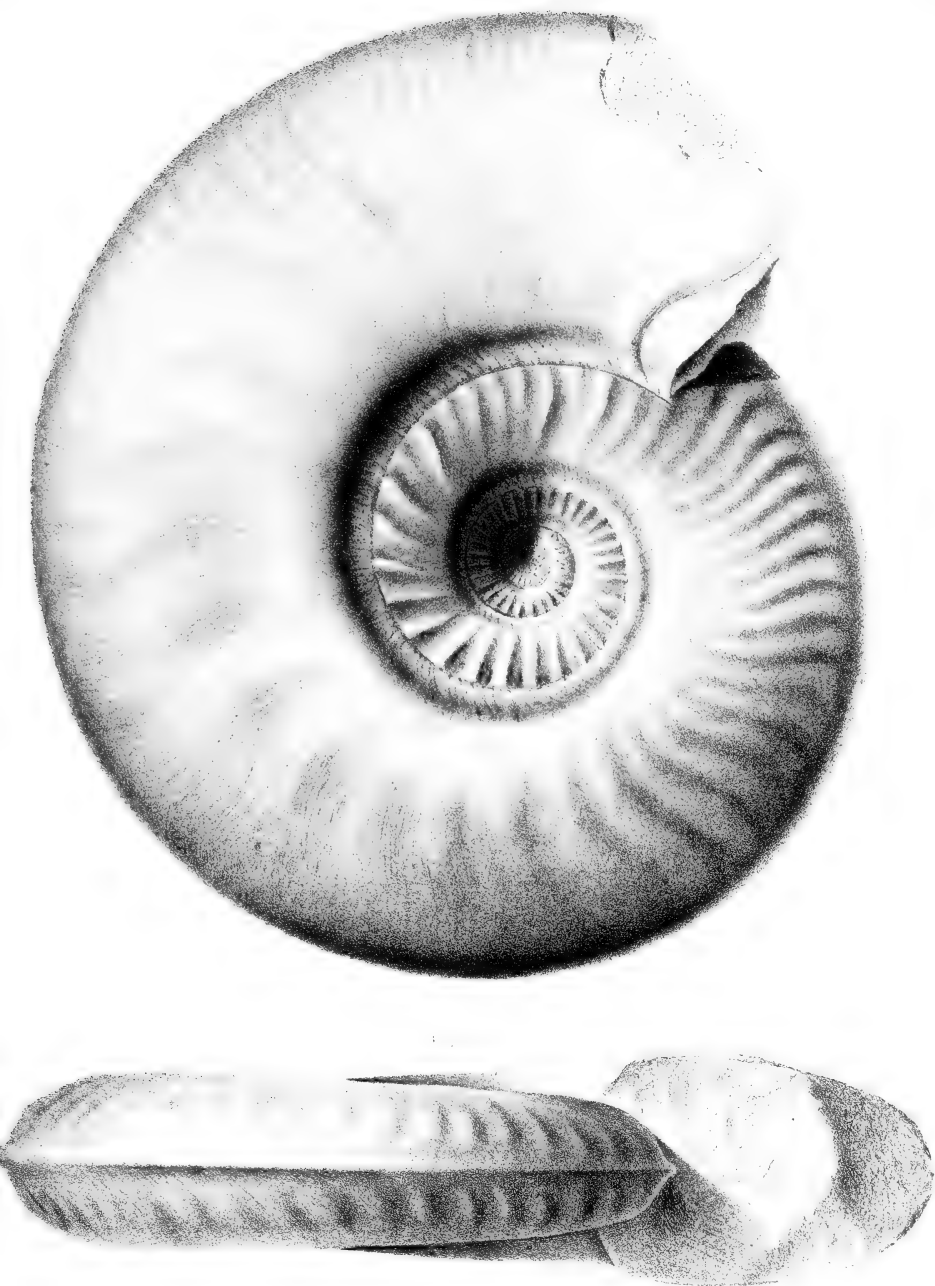
PLATE I.

*Murchisonæ-zone.*

LUDWIGIA MURCHISONÆ (*Sowerby*).

Fig. 1.—A large adult specimen with greater portion of body-chamber present. Side view. Natural size. My Collection. Bradford Abbas, Dorset. (Page 17.)

Fig. 2.—Front view.







## PLATE II.

Figs. 1—5.—*LUDWIGIA MURCHISONÆ* (*Sowerby*).

Fig. 1.—This is the original specimen figured by Sowerby in his 'Mineral Conchology,' plate 550. I have had a fresh drawing made of this type for comparison. Side view. Natural size. Natural History Museum, South Kensington. From Holme, near Portree, Isle of Skye. (Page 17.)

Fig. 2.—Front view.

Fig. 3.—Young shell showing nodose primary ribs. Side view. Natural size. My Collection. Bradford Abbas, Dorset. (Page 17.)

Fig. 4.—Front view of same.

Fig. 5.—A drawing of two consecutive suture lines of the original specimen. Their simplicity and the distance between them are seen in fig. 1. (Page 19.)

Figs. 6, 7.—*LIOCERAS CONCAVUM* (*Sowerby*).

Fig. 6.—The original specimen figured by Sowerby in his 'Mineral Conchology,' plate 94. Side view. Natural size. Natural History Museum, South Kensington. From between Ilminster and Yeovil, Somerset. I have had this original specimen redrawn to show its characters accurately.

Fig. 7.—Front view of the same.





Fig 1

Fig 2

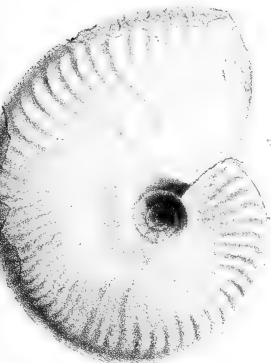
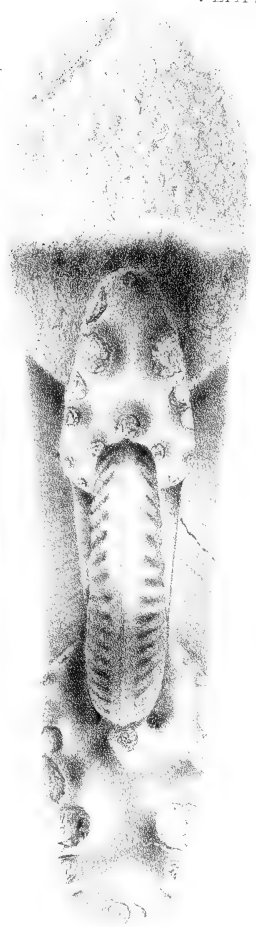


Fig 3

Fig 7

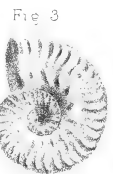


Fig 3



Fig 4

Fig. 5.







### PLATE III.

#### *Murchisonæ-zone.*

Figs. 1—3.—LUDWIGIA MURCHISONÆ (*Sowerby*).

Fig. 1.—A typical specimen; test complete; middle age; showing the passage of the ribs into mere lines of growth. Side view. Natural size. Bradford Abbas, Dorset. My Collection. (Page 17.)

Fig. 2.—Front view, showing plain ventral area.

Fig. 3.—A specimen with slightly larger umbilicus, showing mouth border with lateral lappet. It should be observed that the ribs continue well marked right up to the mouth border. Natural size. My Collection. From near Halfway House, Dorset. (Page 17.)

Figs. 4, 5.—LUDWIGIA MURCHISONÆ, var. OBTUSA (*Quenstedt*).

Fig. 4.—Side view of specimen without much shell but showing a tendency to develop spines. Natural size. My Collection. From near Beaminster, Dorset. (Page 17.)

Fig. 5.—Front view, showing the coarseness of the ribs and the squareness of the section.

Figs. 6, 7.—LUDWIGIA MURCHISONÆ, var. BAYLI, *S. Buckman*.

Fig. 6.—Side view. Showing small umbilicus and fine and numerous ribs. Natural size. In my Collection. Probably from Bradford Abbas. (Page 18.)

Fig. 7.—Front view, showing section. The keel is drawn too sharp and prominent, and the ventral area should be flatter and rather more angular, thus giving the shell a squarer appearance.



Fig. 6.

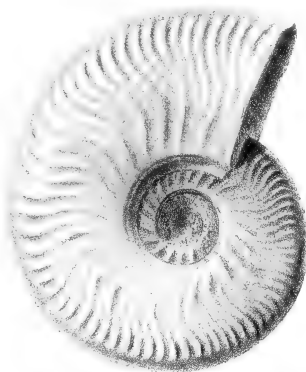
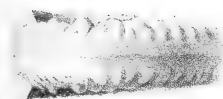


Fig. 7







## PLATE IV.

### *Sowerbyi-zone.*

Figs. 1—4.—*LUDWIGIA CORNU*, *S. Buckman*.

Fig. 1.—Side view of a specimen with open umbilicus, showing lateral lappet. Natural size. My Collection. Near Halfway House (Sherborne), Dorset. (Page 20.)

Fig. 2.—Front view of the same, to show section.

Fig. 3.—Side view of a specimen with small umbilicus, showing the termination. Natural size. My Collection. Bradford Abbas, Dorset. (Page 20.)

Fig. 4.—Back view of ditto, showing the prominent keel.

### *Murchisonæ-zone.*

Figs. 5—8.—*LIOCERAS BRADFORDENSE*, *S. Buckman*.

Fig. 5.—Side view of a specimen about half-grown, showing a regularly coiling centre and termination to body-chamber. Natural size. My Collection. Bradford Abbas, Dorset. (Page 22.)

Fig. 6.—Front view of ditto.

Fig. 7.—Side view of young shell. Natural size. My Collection. Halfway House, Dorset. (Page 22.)

Fig. 8.—Suture lines as shown by the specimen figured on the next plate. (Page 24.)



Fig. 1

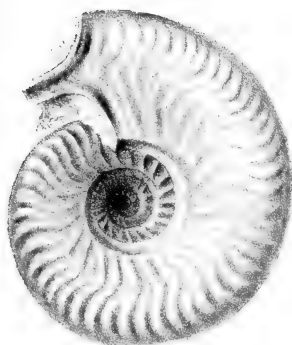


Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6



Fig. 7



Fig. 8







PLATE V.

*Murchisonæ-zone.*

LIOCERAS BRADFORDENSE (*S. Buckman*).

Fig. 1.—Nearly adult specimen, showing the peculiar ribbing in centre, also the rather quick expansion of the centre after a certain size, thus giving the shell a much flatter appearance. Specimens much larger have been met with, but imperfect. Natural size. My Collection. From near Beaminster, Dorset. The whole of the body-chamber is present. (Page 22.)

Fig. 2.—Front view. The keel is scarcely more conspicuous where the test is present.







## PLATE VI.

*Sowerbyi-zone.*

LIOCERAS CONCAVUM (*Sowerby*). Var. A.

Fig. 1.—Large adult specimen, showing the greater portion of the termination of the body-chamber, also the peculiar increase in the width of the umbilicus, due to the recession of the inner margin of the body-chamber from the regular line of coil round the centre. The umbilicus (which is not quite distinctly shown in the figure) is, until about the last whorl, regularly hollow like the inside of a thimble-top, the inner whorls not projecting at all. The inner area of the whorl is also shown somewhat too flat, and the outer area is too steep. Side view. Natural size. My Collection. Bradford Abbas, Dorset.

Fig. 2.—Front view of same, showing the small amount of keel possessed in adult age. The inclusion is rather more than is shown.



Fig. 1

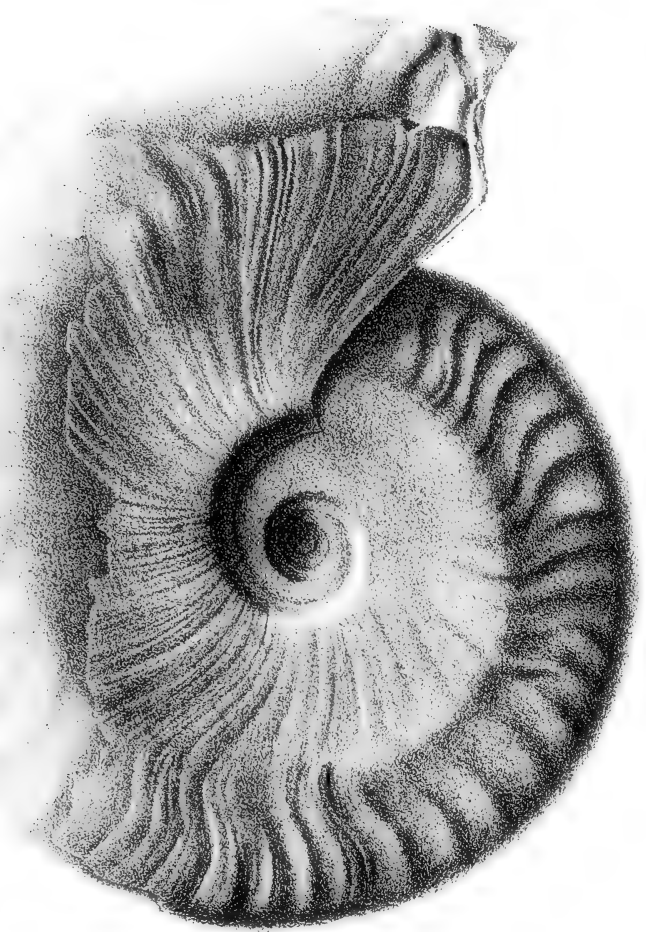


Fig. 2

Harbor map







THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

VOLUME FOR 1886.

L O N D O N :

MDCCCLXXXVII.



THE  
BRITISH  
PLEISTOCENE MAMMALIA.

BY

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PROFESSOR OF GEOLOGY AND PALEONTOLOGY IN OWENS COLLEGE.

PART VI.  
BRITISH PLEISTOCENE CERVIDÆ.

(PAGES 1—29. PLATES I—VII.)

LONDON :  
PRINTED FOR THE PALEONTOGRAPHICAL SOCIETY.

1887.

PRINTED BY  
ADLARD AND SON, BARTHOLOMEW CLOSE.



MONOGRAPH  
ON  
THE BRITISH MAMMALIA  
OF THE  
PLEISTOCENE PERIOD.

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Order—**UNGULATA.**

SUB-ORDER—*ARTIODACTYLA.*

FAMILY—**CERVIDÆ.**

*Genus*—**ALCES.**

Species—*Alces latifrons*, Dawkins.

*Cervus latifrons*, Johnson.

*C. bovides*, Gunn, MS.

CHAPTER I.

PL. I.

§ 1. *Introduction.*

§ 2. *Description and Identification of Skull.*

§ 3. *Description and Identification of Antlers.*

§ 4. *Relation to *Alces machlis*, and Range in  
Space and Time.*

§ 1. *Introduction.*—The numerous fossil Cervine remains of Pleiocene and Pleistocene age, which are preserved in the museums of Britain, France, and Italy, have been for the most part ignored by palæontologists on account of the variability in the form of the antlers at various ages, and because some of them belong to types which have left no living representatives behind to show what they were. During the last twenty-four years I have been collecting materials to fill up this blank in our knowledge, and have

studied in the course of my work the remains in the principal collections at home and on the Continent.<sup>1</sup>

The following Monograph is founded principally on specimens recently collected by Mr. James Backhouse, of York, Mr. Savin, of Cromer, Mr. J. J. Colman, M.P., of Norwich, Mr. W. M. Crowfoot, of Beccles, and Mr. E. T. Dowson, of Geldestone, as well as on specimens in the Museums of Norwich (Gunn Collection), York, of the Geological Survey, and in the British Museum.<sup>2</sup>

In most of the principal collections from the Forest Bed of Norfolk are certain skulls hitherto unnamed, remarkable for their great frontal width, and variously-named antlers characterised by the absence of tines on the beam, by the bovine-like sweep of the beam from the frontals, and in the larger and more perfect specimens by the flattening which implies the existence of a palmated crown. For one of the less perfect specimens Mr. Gunn has proposed the name of *Cervus bovides*,<sup>3</sup> and two of the palmated antlers have been described by Mr. Randall Johnson under the name of *Cervus latifrons*. The whole of these remains I am now able to unite under one species, *Alces latifrons*, and to bring it into close relation with the aberrant cervine form, the Elk (*Alces machlis*), now inhabiting the north-temperate and arctic regions of the Old and New Worlds.

§ 2. *Description and Identification of the Skull*.—The materials for the definition of the skull of *Alces latifrons* consist of two hinder parts of the skull respectively in Mr. Savin's collection and in the British Museum, a frontlet in the Norwich Museum, and portions of nine frontal bones attached to antlers in the above-mentioned collections, and in those of Mr. Randall Johnson and Mr. Backhouse. In Mr. Savin's specimen from the Weybourn beds, East Runton (Pl. I, fig. 1), in which the left antler is attached to the skull, the principal characters are these. The occipital crest is strongly marked and stands well back from the occipito-parietal suture. The frontals are very tumid between the antlers, and, together with the antler-pedicles, *p e*, present a peculiar broad forehead (Tables I, II, and III), from which the antler springs at right angles in the same plane as the frontals, instead of at an angle with the frontal plane,<sup>4</sup> as is the case with all other Deer with the exception of *Alces* (Pl. I, fig. 7).

These characters are repeated in the second skull in the British Museum, which was dredged on the Dogger Bank, and which, evidently from its highly mineralised condition and the adherent fragments of red ferruginous matrix, has been derived from the Forest Bed. They are also repeated in a frontlet in Mr. Gunn's collection (Pl. I, fig. 2), now in the Norwich Museum, and referred by him to *Cervus bovides*. It is a singularly massive bone, and presents a thickness of 1·25 inch in the line of the interfrontal suture. This

<sup>1</sup> See various papers in the 'Quarterly Journal of the Geol. Soc., London,' vols. xxiv, xxvii, xxxiv.

<sup>2</sup> I take this opportunity of thanking these gentlemen, and the curators of the various Museums, for the facilities which I have enjoyed of studying the specimens.

<sup>3</sup> 'Memoirs of the Geological Survey of England and Wales,' E. T. Newton "On the Vertebrata of the Forest Bed Series," 1882, p. 52.

<sup>4</sup> The frontal plane is measured in the frontal region between the antlers.

character, as Mr. Gunn pointed out to me, would give an advantage to the old males in their contests, and would protect the forehead, which is unprotected by the antlers, from a blow delivered in front. The width of the frontals, including the bases of the pedicles, is in this specimen 8 inches.

In the nine frontals with antlers attached (Pl. I, figs. 3, 4, 5, 6), the pedicle is in the frontal plane, with one exception in Mr. Backhouse's collection, in which the main axis of the antler is at an angle of  $8^{\circ}$  to the frontal plane. The pedicles are very short, ranging from 1 to  $1\frac{1}{2}$  inches in length.

The great width of the frontals between the antlers, to which the species owes its name, is indicated in Table II by the measurement from the interfrontal suture to the bur, which ranges from 3·8 to 4·8 inches, while in the *Alces machlis* it ranges from 2·9 to 3·75 inches. This implies a width of forehead ranging from 7 to 9 inches in the fossil as compared with 6 to 7 inches in the living Elk. With this exception I am unable, after a careful comparison of the fossil with eleven skulls of *Alces machlis* in the British Museum and the College of Surgeons (Pl. I, figs. 1 and 7), to discover any specific difference between them. There are, however, as may be seen in Table I, variations which are too small to deserve further notice. It will further be seen that the fossil skulls are smaller than those of the living Elk. The pedicle is short in both, and the frontal angle, *i. e.* angle measured from frontal plane between the antlers (see Table II), presents the same range of variation in both from  $0^{\circ}0'$  to  $8^{\circ}$ , and the pedicle as a rule being in the frontal plane.

TABLE I.—*Comparative Measurements<sup>1</sup> of Skulls of Alces latifrons and A. machlis.*

	Alces latifrons.		Alces machlis.		
	Weybourn Beds, East Ranton, Coll. Savin, Pl. I, fig. 1.	Dredged off Dogger Bank, Owies' Coll., Brit. Mus., 46108.	Brit. Mus., Male.	Coll. Surgeons, 1627. Male. Sweden, Pl. I, fig. 7.	Coll. Surgeons, 1626. Male. New Carolina.
Occipital height .....	4·0	4·1	4·5	5·0	5·0
Occipital width .....	5·3	5·0	4·5	5·0	5·0
Mastoid width .....	—	6·0	6·5	6·8	6·7
Occipital foramen, width .....	1·3	—	1·7	1·6	—
Occipital foramen, height .....	1·3	1·5	1·9	1·9	—
Occipital foramen to occipital crest .....	2·7	2·4	3·0	3·0	3·4
Antero-posterior length of parietals ...	2·0	2·5	3·2	4·5	3·9
Mastoid to mastoid (tape) .....	9·3	8·5	9·0	12·3	—
Occipital crest to antler base .....	4·0	3·0	4·7	4·6	4·5
Occipital crest to parieto-frontal suture .....	4·0	3·5	4·5	4·5	4·6
Occipital crest to occipito-parietal suture .....	1·4	1·2	1·3	2·0	1·3

<sup>1</sup> All the measurements are taken in inches and tenths.

§ 3. *Description and Identification of Antlers.*—The series of fifteen antlers belonging to this form, of which nine are attached to the frontals, confirm the evidence offered by the skulls that the animal to which they belonged was an Elk, but specifically different from the *Alces machlis*. The bur (Pl. I, *a*) is stout, and at right angles or nearly so to the main axis of the beam. The beam is cylindrical (figs. 1, 3, 4, 5, 6), strongly grooved, and without tines up to the beginning of the palmation of the crown. In the most perfect specimen, figured and described by Mr. Johnson<sup>1</sup> as *Cervus latifrons*, the first tine of the palm (fig. 6, *c*) is preserved, sweeping forwards as in the living Elk (fig. 7), and presenting an arc which measures 37 inches from the interfrontal suture. The rest of the palm, including tine *c*, is broken away. The beam curves slightly downwards and then upwards, and begins to be flattened at a distance of 12 inches from the bur, the basal portion sweeping away in the frontal plane at right angles to the frontals. A second specimen in the Norwich Museum, and referred by Mr. Johnson to the same species, also measures 12 inches from the bur to the beginning of the palmation. Two antlers in the collection of Mr. Savin, the one attached to the skull (fig. 1) and the other (fig. 5) to a fragment of frontal bone, possess longer and more sigmoid beams than the two antlers above described, the beginning of the palmation being 16 inches from the bur in the one and 15 inches in the other (see Table II). This difference, however, is probably not of specific, or even of varietal, value when viewed in the light of a similar variation in the antlers of *Alces machlis*, in which the measurement ranges from a minimum of 5 to a maximum of 7 inches (see Table III). In other words, the variation taken in relation to the length of beam from bur to palmation is 25 per cent. in the fossil, while it rises to 28 per cent. in the living Elk.

These characters are repeated in the antler referred to *Cervus bovides* by Mr. Gunn. The decrease in the circumference of the beam in this specimen from the bur to the fractured end, below the palmation, noticed by Mr. E. T. Newton,<sup>2</sup> is the rule rather than the exception in the whole series. In this case the beam is broken at 9 inches from the bur, or 3 inches below the point where the palmation begins in the antler, fig. 6.

The beam, as may be seen in the tables of measurements (Tables II and III), is much longer (more than twice as long) in the fossil than in the recent *Alces*. This greater length is the only specific character which is revealed by the series of broken antlers which have been examined.

<sup>1</sup> 'Ann. and Mag. of Nat. Hist.,' 4th series, 1874, vol. xiii, p. 1, pl. i.

<sup>2</sup> Op. cit., p. 58.

TABLE II.—*Measurements of Skulls and Antlers of Alces latifrons.*

Alces latifrons.					
	Interfrontal suture to bur.	Frontal angle.	Basal circumference of antlers.	Bur to palmation.	Extreme length.
Forest Bed, Sidestrand. Savin Coll. (Pl. I, fig. 5) .....	—	0°0	6·0	16·0	21·5+
Forest Bed, Pakefield. Backhouse Coll. ....	—	8°	6·8	—	—
Dredged. Layton Coll. British Museum .....	—	—	6·8	—	—
Elephant Bed, Bacton. Norwich Museum .....	—	—	7·4	—	—
Forest Bed. Norwich Museum. <i>Cervus bovides</i> , Gunn .....	4·0	0·0	7·6	—	9·0+
Forest Bed, Kessingland. Norwich Mus. ....	4·0	0·0	—	—	—
Weybourn Beds, Cromer. Savin Coll. (Pl. I, fig. 3) .....	5·8	0·0	7·8	—	11·8+
Forest Bed, Hasborough. Johnson Coll. <i>Cervus latifrons</i> , Johnson. (Pl. I, fig. 6) .....	4·8	0·0	8·4	12·0	19·1+
Weybourn Beds, East Ranton. Savin Coll. (Pl. I, fig. 1) .....	4·0	0·0	8·4	15·0	21·5+
Forest Bed. Norwich Museum .....	—	—	9·1	12·0	22·0+
Forest Bed, Overstrand. Savin Coll. (Pl. I, fig. 4) .....	4·8	0·0	9·6	—	7·5+
Dredged off Dogger Bank. British Museum .....	—	—	11·5	—	—
Dredged off Dogger Bank. British Museum .....	4·0	—	—	—	—

TABLE III.—*Measurements of Skulls and Antlers of A. machlis.*

Alces machlis.					
	Interfrontal suture to bur.	Frontal angle.	Basal circumference of antlers.	Bur to palmation.	Bur to fork.
British Museum .....	3·75	4°	6·5	5·0	12·0
„ .....	3·25	0·0	6·9	5·0	8·0
„ .....	2·9	4°	6·9	7·0	10·5
„ .....	3·75	0·0	7·5	5·0	9·8
„ .....	3·5	8°	7·5	5·5	10·2
„ .....	3·25	0·0	7·5	5·0	10·2
„ .....	3·75	0·0	8·0	5·0	10·0
Royal College of Surgeons .....	3·75	0·0	6·4	5·3	9·4
„ „ .....	3·2	2°	8·3	5·3	9·0

§ 3. *Description and Identification of Antlers.*—The series of fifteen antlers belonging to this form, of which nine are attached to the frontals, confirm the evidence offered by the skulls that the animal to which they belonged was an Elk, but specifically different from the *Alces machlis*. The bur (Pl. I, *a*) is stout, and at right angles or nearly so to the main axis of the beam. The beam is cylindrical (figs. 1, 3, 4, 5, 6), strongly grooved, and without tines up to the beginning of the palmation of the crown. In the most perfect specimen, figured and described by Mr. Johnson<sup>1</sup> as *Cervus latifrons*, the first tine of the palm (fig. 6, *c*) is preserved, sweeping forwards as in the living Elk (fig. 7), and presenting an arc which measures 37 inches from the interfrontal suture. The rest of the palm, including tine *c*, is broken away. The beam curves slightly downwards and then upwards, and begins to be flattened at a distance of 12 inches from the bur, the basal portion sweeping away in the frontal plane at right angles to the frontals. A second specimen in the Norwich Museum, and referred by Mr. Johnson to the same species, also measures 12 inches from the bur to the beginning of the palmation. Two antlers in the collection of Mr. Savin, the one attached to the skull (fig. 1) and the other (fig. 5) to a fragment of frontal bone, possess longer and more sigmoid beams than the two antlers above described, the beginning of the palmation being 16 inches from the bur in the one and 15 inches in the other (see Table II). This difference, however, is probably not of specific, or even of varietal, value when viewed in the light of a similar variation in the antlers of *Alces machlis*, in which the measurement ranges from a minimum of 5 to a maximum of 7 inches (see Table III). In other words, the variation taken in relation to the length of beam from bur to palmation is 25 per cent. in the fossil, while it rises to 28 per cent. in the living Elk.

These characters are repeated in the antler referred to *Cervus bovides* by Mr. Gunn. The decrease in the circumference of the beam in this specimen from the bur to the fractured end, below the palmation, noticed by Mr. E. T. Newton,<sup>2</sup> is the rule rather than the exception in the whole series. In this case the beam is broken at 9 inches from the bur, or 3 inches below the point where the palmation begins in the antler, fig. 6.

The beam, as may be seen in the tables of measurements (Tables II and III), is much longer (more than twice as long) in the fossil than in the recent *Alces*. This greater length is the only specific character which is revealed by the series of broken antlers which have been examined.

<sup>1</sup> 'Ann. and Mag. of Nat. Hist.,' 4th series, 1874, vol. xiii, p. 1, pl. i.

<sup>2</sup> Op. cit., p. 58.

TABLE II.—*Measurements of Skulls and Antlers of Alces latifrons.*

	Alces latifrons.				
	Interfrontal suture to bur.	Frontal angle.	Basal circumference of antlers.	Bur to palmation.	Extreme length.
Forest Bed, Sidestrand. Savin Coll. (Pl. I, fig. 5)	—	0°0	6·0	16·0	21·5 +
Forest Bed, Pakefield. Backhouse Coll.	—	8	6·8	—	—
Dredged. Layton Coll., British Museum	—	—	6·8	—	—
Elephant Bed, Bacton. Norwich Museum	—	—	7·1	—	—
Forest Bed. Norwich Museum. <i>Cervus</i> <i>bovides</i> , Gunn	4·0	0°0	7·6	—	9·0 +
Forest Bed, Kessingland. Norwich Mus.	4·0	0°0	—	—	—
Weybourn Beds, Cromer. Savin Coll. (Pl. I, fig. 3)	5·8	0°0	7·8	—	11·8 +
Forest Bed, Hasborough. Johnson Coll. <i>Cervus latifrons</i> , Johnson. (Pl. I, fig. 6)	4·8	0°0	8·4	12·0	19·1 +
Weybourn Beds, East Rulton. Savin Coll. (Pl. I, fig. 1)	4·0	0°0	8·4	15·0	21·5 +
Forest Bed. Norwich Museum	—	—	9·1	12·0	22·0 +
Forest Bed, Overstrand. Savin Coll. (Pl. I, fig. 4)	4·8	0°0	9·6	—	7·5 +
Dredged off Dogger Bank. British Museum	—	—	11·5	—	—
Dredged off Dogger Bank. British Museum	4·0	—	—	—	—

TABLE III.—*Measurements of Skulls and Antlers of A. machlis.*

	Alces machlis.				
	Interfrontal suture to bur.	Frontal angle.	Basal circumference of antlers.	Bur to palmation.	Bur to fork.
British Museum	3·75	4°	6·5	5·0	12·0
"	3·25	0°0	6·9	5·0	8·0
"	2·9	4°	6·9	7·0	10·5
"	3·75	0°0	7·5	5·0	9·8
"	3·5	8°	7·5	5·5	10·2
"	3·25	0°0	7·5	5·0	10·2
"	3·75	0°0	8·0	5·0	10·0
Royal College of Surgeons	3·75	0°0	6·4	5·3	9·4
"	3·2	2°	8·3	5·3	9·0

§ 4. *Relation to Alces machlis, and Range in Space and Time.*—In the foregoing remarks it has been proved that the *Alces latifrons* is specifically distinct from *Alces machlis* in its greater breadth of forehead and in the longer beams of the antlers. It must further be noted that no remains of *Alces machlis* have been found in the strata of the same geological age as the Forest-bed series, its earliest appearance in Britain being in the peat bogs and alluvia of Prehistoric age.<sup>1</sup> Nor am I aware of the discovery of its remains in any Pleistocene deposit on the Continent.

The antler engraved on a slab of mica schist by the Cave Men and found in the Late Pleistocene cave of Les Eyzies, and a lower jaw in the Oxford Museum from Llandebie Cave, near Swansea, are referred by Prof. Edouard Lartet to the Elk.<sup>2</sup> The former, however, belongs to the Reindeer,<sup>3</sup> and the latter to the *Cervus megaceros*.

The *Alces latifrons* has up to the present time only been found in one or other of the Early Pleistocene<sup>4</sup> deposits of Norfolk and Suffolk, and is unrepresented in any of the collections which I have examined on the Continent. It is, therefore, earlier in time than the *Alces machlis* according to the present evidence. It may with great probability be taken to be an ancestral form, in which the palmated extremity of the antler did not encroach on the beam to the same extent as in the living Elk. This conclusion is strengthened by the consideration of the changes in antler-development in the living Elk in its passage from youth to old age. In the young antler the palmated crown is confined to the end of the antler, while the palmation with advancing years encroaches more and more on the beam, and ultimately occupies the whole antler above the tine.<sup>5</sup>

The *Alces latifrons* and the *A. machlis* are the only representatives hitherto known of the aberrant cervine genus *Alces*.

<sup>1</sup> For the range of the Elk in the Prehistoric strata of Britain, see Dr. A. Smith, 'Proceed. Soc. Antiq., Scotland, ix.

<sup>2</sup> 'Revue Archeologique,' 1864, "Cavernes du Perigord," p. 24, separate copy.

<sup>3</sup> Lartet and Christy, 'Reliquiæ Aquitanicæ,' 4to. A, pl. xxix, fig. 5, p. 127.

<sup>4</sup> I cannot accept the view of Mr. Clement Reid ('Memoirs of the Geological Survey,' "The Geology of the Country around Cromer," 8vo, 1882) that these beds belong to the Pleiocene, because it is negatived by the presence of at least twenty-one living species of the higher Mammalia, including such forms as the Spotted Hyæna (*H. crocuta*), the Glutton, the Musk Sheep, the Horse, the Roe, and the Red Deer, and of such characteristic Pleistocene species as the Cave Bear and the Mammoth. To this list Mr. Savin has recently added the Otter by his discovery of a jaw in the Weybourn Beds at East Runton. The presence of these animals proves that the Forest-bed series belongs to the Pleistocene, or that period when the living higher Mammalia were abundant, and not to the Pleiocene, in which there were only some three or four of the higher Mammalia present in Europe. The whole group of Mammalia in the Forest-bed series is distinctly of Pleistocene *facies*. See 'Quart. Journ. Geol. Soc., Lond.,' xxxix, p. 579; see also Lyell, 'Antiquity of Man,' chap. xii; and Dawkins, 'Early Man in Britain,' chap. vi.

<sup>5</sup> Blasius, 'Fauna der Wirbelthiere Deutschlands,' I, Säugethiere, 8vo, p. 437.



## CHAPTER II.

Pl. II, Pl. III, fig. 1.

Genus—CERVUS.

Species—*Cervus Dawkinsi*, Newton.*Cervus Fitchii*, Gunn, MS.*Cervus Gunnii*, Newton.§ 1. *Introductory.*§ 2. *Definition.*§ 3. *Measurements.*§ 4. *Relation to other Species.*§ 5. *Range in Space and Time.*

§ 1. *Introduction.*—In the preceding chapter a singular form of the genus *Alces* has been described, which is probably the ancestor of the *Alces machlis*. In the present I propose to deal with one of the Deer belonging to the flat-antlered series, which, unfortunately, is as yet only represented by antlers more or less broken. Among the antlers referred to *Cervus verticornis* in my communication to the Geological Society in 1872,<sup>1</sup> was one which Mr. E. T. Newton, in his recent memoir on “The Vertebrates of the Forest-Bed Series,” very justly ascribes to another and different species, to which he gives the above name. I am now able to bring the solitary specimen on which his species is based more completely into relation with other remains, and to define the variations presented by the antler at different ages.

§ 2. *Definition.*—The antler taken by Mr. E. T. Newton as the type of his species is in the Museum of the Geological Survey in Jermyn Street, and is characterised by the following points (Pl. II, fig. 1):—The bur, *a*, is very oblique to the main axis of the beam, and the first tine, *b*, springs directly from the base of the antler, close to the bur. It is oval in section, and is directed forwards and downwards, and is remarkably small in proportion to the size of the beam. The beam above the first tine, *b*, is rounded on its postero-inner aspect, and traversed by a web on its antero-outer surface which connects tine *b* with the second tine, *c*, both tines springing from the beam in the same plane. The second tine, *c*, is flattened at the base and presents a flattened oval section. Above it the beam is webbed on the antero-outer side, giving off tine *e*, or the fourth in a plane higher than tine *c*. This merges into the palmated apex, *f*, *g*, which consists of two, or possibly more points. The third tine, *d*, also flattened oval in section, springs from the postero-inner side of the beam opposite the interspace between tines *e* and *f*.

The basal portion of an antler in the Oxford Museum, obtained by Miss Gurney

<sup>1</sup> ‘Quart. Journ. Geol. Soc.,’ Lond., vol. xxviii, p. 405.

from Cromer, presents all the characters of this singular form, and among them may be noted the small size of tine *b* and its position almost on the bur. These two specimens, as may be seen in the table of measurements, are nearly of the same size, and therefore of the same approximate age.

A larger and older antler (Pl. II, fig. 2) in Mr. Gunn's Collection in the Norwich Museum, and figured by that gentleman as a new species, *Cervus Fitchii*, but as yet without definition, possesses all the essential characters of the antler described above, with the solitary exception of the first tine. This, however, may perhaps be represented by the "offer," fig. 2, *b'*, which appears on the antero-superior surface of the beam at 1.9 inches from the bur. The bur is oblique, and the base of the beam cylindrical and flattened superiorly. The second tine, *c*, occupies the same position in relation to the bur, as in *Cervus Dawkinsi*, and the third, *d*, and fourth, *e*, tines are in the same relative positions on the beam, *d*, being opposite to the interspace between *c* and the next tine above it on the anterior edge of the crown. The second and fourth tines, *c* and *e*, are directed forwards and slightly downwards, and the palmation may be said to begin at the base of tine *e*, which is in a lower plane than tine *c*. The wide and flattened crown is formed by the development of two additional tines, *h* and *i*, one in front and the other behind the two terminal tines, *f* and *g*, of fig. 1, and consists of six tines, inclusive of *d* and *e*, three, *d*, *i*, *g*, being on the posterior side of the main axis of the beam, and two, *e* and *h*, on the anterior side, their position being indicated by a thickening of the fractured surfaces. In the younger antler (fig. 1) there are but four points in the crown.

The general sweep of antler from the bur to the crown is sigmoid, and the crown curves forward and upwards, as is the case with the antlers of *Cervus dama*.

It is obvious from the above description, and from the comparison of figures 1 and 2, that the only difference which can be claimed to be of specific value between the *Cervus Dawkinsi* of Mr. Newton and the above larger and older antler, is the presence of the first tine, *b*, in the former, which, it must be noted, is small and abnormally close to the bur. The value of this as a specific character may be tested by its application to the antlers of other species. In the case of *Cervus verticornis* found in the same deposits (see Chapter V), a small first tine is developed in some individuals, and in the case of the Reindeer the same variability is to be seen. The evidence, therefore, seems to be sufficient to group these two antlers together under one specific name, and I cannot accept Mr. Newton's (op. cit., pp. 55, 56) conclusion that they are specifically distinct—a conclusion that is based partly on the assumed specific value of the first tine in the one, and partly on the very imperfect figure which Mr. Gunn has lithographed of the other.

The comparative measurements of these two antlers are given in the subjoined table.

The antler (Pl. III, figs. 1 and 1, A) discovered by Mr. A. C. Savin in the Forest bed at Sidstrand, Cromer, presents points which are common to both of the above specimens (Pl. II, figs. 1 and 2). The web passing downwards from tine *c* to the base

in Pl. II, fig. 1, is combined with a great development of the offer *b'*, of Pl. II, fig. 2, which assumes the shape of a small cylindrical tine springing at a distance of two inches from the bur.

Nor can I accept as a valid species the *Cervus Gunnii* which Mr. Newton (op. cit., p. 57) has founded on my rough notes in a manuscript catalogue of the King Collection in the Museum of the Geological Survey, which were never intended for publication. It is a water-worn fragment with an oblique bur, a portion of which, with a part of the antler base on the antero-outer side, has been broken away. This fractured surface occupies the position of the first tine, *b*, in *Cervus Dawkinsi*, and probably implies that a first tine has been forcibly rent away. The second tine, *c*, presents a flattened, oval section at its base, and is situated at a higher plane than the fractured surface of the bur. From the second tine up to the broken end the beam becomes more and more flattened. In all respects this fragment belongs to the same series as *Cervus Dawkinsi*, and the question as to its having possessed a first tine or not is rendered of no importance by its identity of form in other respects with that species.

A second basal fragment of a shed antler in the Collection of Mr. Randall Johnson is nearly of the same size as the above. It is, however, beyond all doubt without a first tine, *b*.

§ 3. *Measurements*.—The antlers in the following table are arranged according to their basal circumference, and the measurements are taken in inches. The variation in the measurements of the first or youngest, and the last or oldest, is normal in the development of antlers in the Cervidæ, and is merely the result of their natural growth.

*Measurements of Antlers of Cervus Dawkinsi.*

	Forest Bed, Cromer, Oxford Museum.	Forest Bed, King Coll., Geol. Survey, Pl. II, fig. 1.	Forest Bed, Side- brand, Cromer, Coll. Savlin, Pl. III, figs. 1, 1a.	Forest Bed, Mundea- ley, King Coll., Mus. Geol. Surv., "Cervus Gunnii."	Forest Bed, Coll. Randall Johnson.	Forest Bed, Barton, Norwich Mus., C. <i>Pitchii</i> , Gunn, Pl. II, fig. 2.
Circumference of beam above bur ( <i>a</i> ) ...	4.9	4.9	5.6	7.0	7.2	8.4
Bur to fork of tine 1 ( <i>b</i> ) .....	0.8	1.5	—	—	—	—
Circumference of tine 1 .....	—	2.75	—	—	—	—
Tine 1 to tine 2 ( <i>c</i> ) .....	2.0	2.0	—	—	—	—
Bur to tine 2 .....	—	—	3.5	4.5	5.0	3.0
Bur to fork of tine 2 .....	—	5.5	6.5	7.5	—	6.0
Circumference of beam above tine 2 .....	—	5.6	7.5	8.2	—	—
Tine 2 to tine 4 ( <i>e</i> ) .....	—	1.7	—	—	—	2.0
Diameter of base of tine 4 .....	—	—	—	—	—	3.2
Bur to fork of tine 4 .....	—	9.0	—	—	—	12.0
Circumference of beam above tine 4 .....	—	7.5	—	—	—	—
Bur to tine 3 ( <i>d</i> ) .....	—	6.5	—	5.5	8.0	9.0
Bur to fork of tine 3 .....	—	—	5.6	—	10.0	—
Total length .....	—	12.0+	12.0+	—	11.9+	21.5+

§ 4. *Relation to other Species*.—The next question to be considered is the relation of *Cervus Dawkinsi* to other cervine species. The only form with which I am able to bring it into any kind of relation is the *Cervus megaceros*. If figs. 1 and 2 of Plate II be compared with the antler of that species, it will be seen that the far larger and more palmated form of the latter is outlined in the former. The back tine, *d*, is in the same position in both, and the first tine, *b*. In the latter, however, the palmation extends down from the crown as far as the second tine *c*, instead of stopping short at the fourth tine, *e*, as in the former. It must also be noted that in the former the development of a brow-tine is as irregular as in the case of the Reindeer, while it is constant in the latter. I am, however, after taking all these points into account, unable to bring these two forms into direct relation. Nor can I establish a relation between it and any other species, recent or fossil.

§ 5. *Range in Space and Time*.—All the specimens described above are derived from the pre-glacial Forest Bed of Norfolk, in the neighbourhood of Cromer. A fragmentary palm in the Collection of Mr. J. J. Colman, M.P., found near Lowestoft in a continuation of the same strata extends its range to the borders of Suffolk. I have hitherto been unable to identify it in the museums of France or Italy. As the evidence stands at present, therefore, the *Cervus Dawkinsi* is a Deer which inhabited the valley of the North Sea in the early Pleistocene age before the lowering of the temperature, which has left its mark in the glacial phenomena of Northern Europe, and before the great submergence during which Britain was represented by a cluster of islets which are now the higher lands of the north and west of Scotland, of the Lake District, and Wales, of the Pennine Chain, and of Devon and Cornwall.

## CHAPTER III.

## Pl. III, figs. 2—5.

*Cervus Savini*, Dawkins.§ 1. *Introductory.*§ 2. *Definition of Antlers.*§ 3. *Measurements of Antlers.*§ 4. *The Skull.*§ 5. *The Relation of Cervus Savini to other species of Deer.*

§ 1. *Introductory.*—In most of the principal museums of this country which possess fossils from the Forest Bed, basal fragments of antlers are to be seen which have hitherto been unnamed and unclassified. They are characterised by the brow-tine springing from the cylindrical beam close to the bur at right or obtuse angles, and the second tine also springing from the beam at right angles, and at a distance of from six to eleven inches from the bur. After searching in vain for many years for a clue to the definition of the perfect antler to which these fragments belong, I am now able to restore the perfect antler and to define the species. The specimens which have allowed me to do this have been discovered at East Runton, Sidestrand, Overstrand, and Trimmingham, by Mr. A. C. Savin, of Cromer, to whom my best thanks are due for his placing his collection at my disposal, and after whom I have named the species.

§ 2. *Definition of Antlers.*—The antler which I have chosen as the type of the species (Pl. III, fig. 3) was obtained at Trimmingham, and measures 25 + inches in length, with the tines broken off, but yet showing sufficient evidence of the form of the crown. It possesses the following characters:—The base is rounded oval, and the bur, *a*, is very stout and oblique to the axis of the basal portion of the beam; the brow-tine, *b*, springs from it at an obtuse angle of from 120° to 137° to the beam in most of the specimens which I have examined. This appears to be its normal relation to the main axis of the basal portion of the beam. Sometimes, however, as in a specimen in the British Museum from the Forest Bed at Happisburgh, No. 33,471, it is at right angles to the beam, and this character is repeated in a specimen from East Runton in the Museum of the Geological Survey. The brow-tine is oval at the base, but, as may be seen in Pl. III, fig. 2, *b*, which represents a young antler from the Weybourn beds of East Runton, it rapidly becomes cylindrical and sweeps forwards. The antler-base is

hollowed below, and flattened above at the point of the origin of the brow-tine, causing the fork of the brow-tine to be webbed. Above the brow-tine the beam is cylindrical, and curves gently upwards to the base of the second tine (figs. 2, 3, *c*). More generally however, this portion of the antler is straight. It also generally bears a ridge, which passes from the fork of the brow-tine to the base of the second tine on the antero-outer side of the beam. This, however, is not present in all the specimens. The second tine (figs. 2 and 3, *c*) springs at right angles or nearly so to the beam, and from a plane which is the same or nearly the same as that of the brow-tine, in this respect differing from the corresponding portion of the antler of *Cervus verticornis* (see Chapter V), which occurs in the same deposits. The beam is flattened at the base of the second tine, above which it rapidly recovers its rounded form, only to lose it again at the base of tine 3 (fig. 3, *d*), which springs from the back of the antler. Above this it presents an oval section, and sweeps forwards and upwards at an angle of  $140^{\circ}$  degrees in the figured specimen, and of  $145^{\circ}$  in a second in Mr. Backhouse's collection, to its bifurcation into two flattened tines, *f* and *g*, which constitute the crown, one being directed forwards and the other backwards at an angle of  $120^{\circ}$ . A second fragment of palm from Kessingland in Mr. W. M. Crowfoot's Collection, shows the equal bifurcation into two tines, *f* and *g*, at an angle of  $118^{\circ}$ , each measuring at its fractured base  $1.8 \times 0.9$  inches.

The beam in the well-preserved specimens is traversed by grooves, which are more strongly marked in the older and larger (fig. 4) than in the younger and smaller individuals. The general curvature of the antlers is sigmoid. As the antlers increase in size they present modifications of form usually met with in the living Deer, such as *Cervus elaphus* and *C. dama*. Sometimes an "offer" is present above the brow-tine, which in an antler base from Overstrand (115, Savin Coll.) is developed into an accessory brow-tine 1.5 inches above it, and giving a measurement of 3.4 inches from the bur to the fork. In a second (Savin Coll.) the "offer" is present, and the normal second tine, *c*, is represented by two small cylindrical tines set in the same transverse plane on the front of the beam. The antlers sweep backwards and forwards after giving off the brow-tine.

As the antlers increase in size, an additional tine makes its appearance on the front of the beam between tine 2, *c*, and the back tine, *d*, as may be seen in a fine basal half of an antler from Overstrand (Pl. III, fig. 4) in Mr. Savin's Collection. It may be remarked that an additional tine is developed in a similar point in old individuals of *Cervus verticornis*.

§ 3. *Measurements of Antlers*.—The following table (pp. 14, 15) represents the variation in size of the antlers of this species. It shows that the second tine, *c*, of the figures is variable in its position on the beam, the minimum distance from the brow-tine, *b*, being 5.3 inches and the maximum 9.6 inches.

It is worthy of remark that some of the antlers bear the characteristic marks of the

teeth of hyænas, so frequently seen on the antlers and bones of animals from the Pleistocene caves. The second tine, *c*, and tine *f* of fig. 3, have been gnawed off. This has probably been the work of the *Hyaena spelæa* or cave variety of the *H. crocuta*, which has been identified by Mr. E. T. Newton<sup>1</sup> and myself<sup>2</sup> as a Forest-bed species.

§ 4. *The Skull*.—Four frontlets bearing antlers of the above type in the Norwich Museum, one in the British Museum, three in the Collection of Mr. Backhouse, and two in that of Mr. Crowfoot, present the following characters. The pedicles are set on at an oblique angle to the plane of the frontals between the antlers; the frontals are slightly convex between the pedicles, and slightly concave or flattened on either side of the interfrontal suture on the forehead, down to the suborbital foramen on either side (Pl. III, fig. 5). They present the following measurements:

	Forest Bed, Kessingland.	Backhouse.	Forest Bed, Norfolk, Norwich Museum.	British Museum.
Frontals, pedicle to pedicle .....	3·0	3·0	3·2	2·1
Suborbital foramen to suborbital foramen .....	3·8	3·8	3·8	—
Circumference of pedicle .....	6·6	5·6	—	6·5
Length .....	1·0	1·5	—	1·1
Frontal angle .....	50°	50°	—	—

§ 5. *The Relation of Cervus Savini to other species of Deer*.—The antlers of *Cervus Savini* differ from all fossil and recent forms with which I am acquainted, but are more closely related to those of the *Cervus Browni* of Clacton, to be described in the next chapter. They differ from those of the living *Cervus dama* in the palmation of the crown being equally in front and behind, instead of being behind the main axis of the beam as is normally the case with the latter.

The antlers of *C. Savini* agree with those of *C. Browni* in the position of the brow-tine and of tines 2 and 4 (Pl. III, figs. 3, 4), and in the relation of tine 3, *d*, to the palmated crown. They also agree with it in the development of a fourth tine on the anterior side between the second tine, *c*, and the crown, and in the general tendency towards anterior palmation. They differ from it in being slightly less palmated, and in the first and second tines being at a right or greater angle to the beam. The older antlers also are much larger. These, however, are small points of difference of no great weight in classification.

<sup>1</sup> 'Geol. Mag.,' 1883.

<sup>2</sup> 'Quart. Journ. Geol. Soc., Lond.,' 1883.

	Forest-Bad Series, Kessing- land (Back- house Coll.).	Overstrand (Savin Collection).	Runton, East (Collection Geological Survey).	Runton (Savin Collection) Pl. III, fig. 2.	Has- borough (British Museum).	Norwich Museum.	Mundes- (Collectio Geologic Survey)
Circumference of base of beam.....	5·8	...	5·8	6·0	7·0	7·4	7·6
Pedicle, length of .....	0·8	...	...	...	1·45	...	...
„ circumference of .....	5·2	...	...	...	6·5	...	...
Bur to fork of tine 1 <i>b</i> .....	1·8	...	2·0	1·5	...	...	1·8
Circumference of beam above tine 1 .....	...	3·3	4·8	4·2	5·0	6·0	5·8
Tine 1, basal circumference of .....	...	...	3·4	4·4	...	...	...
Tine 1 to tine 2 <i>c</i> .....	...	...	4·5	6·0	5·0	...	6·8
Tine 2, basal circumference of .....	...	...	3·9	...	...	...	...
Circumference of beam above tine 2 .....	...	...	4·8	...	...	...	...
Bur to fork of tine 2.....	...	...	7·5	...	...	...	...
Tine 2 to tine 3 <i>d</i> .....	...	...	7·0	...	...	...	...
Bur to tine 3 .....	...	...	...	...	...	...	...
Bur to fork of tine 3.....	...	...	...	...	...	...	...
Circumference of beam above tine 3 .....	...	...	...	...	...	...	...
Tine 2 to tine 4 <i>e</i> .....	...	...	...	...	...	...	...
Bur to fork of tine 4.....	...	...	...	...	...	...	...
Tine 2 to anterior tine of crown .....	...	...	...	...	...	...	...
Tine 3 to posterior tine of crown .....	...	...	...	...	...	...	...
Bur to fork of crown.....	...	...	...	...	...	...	...
Total length .....	...	...	...	...	...	...	...



## 15

[illegible]

*The Range of Cervus Savini.*—The antlers and skulls of *C. Savini* have up to the present time only been discovered in the Forest-bed series, at East and West Runton, Cromer, Sidestrand, Overstrand, Trimingham, Hasborough, Mundesley, and Corton, in Norfolk, and at Pakefield and Kessingland, in Suffolk, in one or other of the local varieties of the Forest-bed series. According to our present knowledge, it is an ancient type of Fallow-deer living in the preglacial forests of the valley of the North Sea, before the *Cervus Browni* or the *Cervus dama* had appeared in Britain.

From these facts it may be concluded that *Cervus Savini* is the ancestral form of both *C. Browni* and *C. dama*.

## CHAPTER IV.

## Pl. IV.

*Cervus Browni*, Dawkins.*Cervus clactonianus*, Falconer.§ 1. *Introduction.*§ 2. *Description of Antlers.*§ 3. *Measurements.*§ 4. *Comparison with Cervus dama.*§ 5. *The Relation of Cervus Browni to C. Savini and C. dama.*

§ 1. *Introduction.*—In the collection of fossil mammals found in the freshwater deposits of Clacton by Mr. John Brown, of Stanway, and now in the British Museum, is a series of antlers, forty-one in number, which Mr. Davies could refer to none of the fossil species of the genus *Cervus*. A careful examination convinced me of the truth of his conclusion, and that they indicate a species of deer hitherto unknown, not only in Britain but also on the Continent. For it I proposed in 1868 the name *Cervus Browni* in memory of its discoverer,<sup>1</sup> to whose indefatigable labour in collecting fossils we owe very much of our knowledge of the Pleistocene Mammalia. Dr. Falconer, whose attention was directed by Mr. Davies to some of these antlers, considered them to belong to a species allied to, but distinct from, the *Axis* of the Crag and Forest Bed,<sup>2</sup> being unaware at the time that the nearly perfect antler, Pl. IV, fig. 3 (which shows that the Clacton deer had no affinities with any round-antlered deer), belonged to the series of fragments which he inscribed in his note-book as those of *Cervus clactonianus*, and considering that the antler in question, which is taken as the type of the species, belonged really to *Cervus dama*,<sup>3</sup> I therefore felt justified in designating the species after its discoverer, instead of adopting Dr. Falconer's manuscript name, which he never attempted to define.

Evidence derived from antlers is, in the main, to be looked upon with suspicion, because of the great variation in form that they present at different ages. In this case,

<sup>1</sup> 'Quart. Journ. Geol. Soc. Lond.,' 1868, p. 511.

<sup>2</sup> 'Palæontological Memoirs,' vol. ii, p. 478. In Brown's Clacton collection in the British Museum is a very extensive series of Deer-horns nearly all belonging to one species. They are all terete, with a single brow-antler given off very low, as in the Val d'Arno *Axis*, but a little lower and pointing more forwards above the brow-antler. There is generally a long reach of beam with no branch. How the beam terminates is not shown. In size it is like Mr. King's *Axis* from the Crag and Forest Bed, but it differs in the brow-antler being given off lower, and in not having the same pronounced double curve. The species is evidently distinct (*Cervus clactonianus*).

<sup>3</sup> Op. cit., vol. ii, p. 480, specimen No. 27,876, quoted as "British Museum specimen of *Cervus dama*."

however, the large number shows that the type was persistent in a group consisting of forty-one animals, no two of the antlers having belonged to the same individual. Those of the right side are twenty-four in number, and out of the whole, fourteen have been forcibly torn from the skull, twenty-five have been shed, and two are mere fragments of tines. Out of them I have chosen a series (Pl. IV, figs. 1—7) to illustrate the characters of the species.

§ 2. *Description of Antlers.*—The antlers (Pl. IV, figs. 1—7) are nearly smooth, being traversed merely by broad and shallow depressions for the reception of the nutrient blood-vessels of the velvet. They are set on the skull obliquely to the axis of the beam, as in the red deer, fallow deer, and Irish elk. The pedicle (fig. 4) is round and short, varying in length from 0·8 to 1·1 inch. The bur, or rose of the Germans, is uncertainly developed, being large and sharply defined in some (figs. 3, 4), and but rudimentary in others. It presents a rounded outline. Immediately above it, the brow-tine, *b*, is given off nearly at right angles to the axis of the beam; the angle, however, varies slightly in different individuals (figs. 3, 4, 5). It is cylindrical in section, with a direction somewhat downward basally, and upward as it tapers to its extreme end. It is sometimes straight. After giving off the brow-tine the rounded beam bends downwards as far as the flattened area, which marks the base of the second tine, *c*, and is also slightly curved forwards. Two antlers present a variation from the ordinary type: in the one a rudimentary tine springs out of the base of the brow-tine, *b*; in the other (fig. 5) an accessory tine, *c'*, which perhaps may be a brow-tine, is thrown off from the beam at a distance of 1·75 inches above the normal brow-tine (*b*). This variation is also found in an antler of a fallow deer in the College of Surgeons. In an antler of *Cervus elaphus*, also in the same collection, there are three brow-tines. The second tine (figs. 2, 3, and 4, *c*) is shaped somewhat like the first; but it springs from a flattened base, so that the section presented is oval. The variations in direction noticed in the brow-tine are repeated also in the second, *c*, and both are nearly of the same length. From the base of the second tine the beam gradually becomes more and more flattened up to the palmated fourth (fig. 3, *e*), which is unfortunately broken in all the specimens; thence it gradually expands into the broad and flattened crown (fig. 3, *d, g, f*), the summit of which has been broken away from the nearly perfect antler, fig. 3, chosen as the type of the species. It presents, however, two broad, oval, fractured surfaces, which meet at the point where the texture becomes dense and hard, indicating that the hard cortical layer of the antler was not far distant, while, on the other hand, the loose texture in the centre of each of these surfaces shows that the crown was prolonged some little distance in their directions. An inference might therefore be drawn that not very much of the apex is lost. It consisted of two, or at most three tines. Fortunately, however, we are not left to guess at the shape of the latter. A broad palmated fragment, possessed of two tines (fig. 7), was associated with the antlers, which cannot be referred to the red deer or Irish elk,

found also at Clacton, while the deep excavation between the tines forbids its being identified with a palmated fragment of antler of reindeer. Therefore the supposition that it belongs to *Cervus Brownei* amounts almost to a certainty, and if so, then it could only belong to the crown. The broad and deep excavation (fig. 7) above mentioned, brings the cortical layer of dense osseous tissue on either side into juxtaposition, and explains exactly why the two layers should be thus brought together at the point of the fractured apex of fig. 3. I have therefore restored the crown of the antler (fig. 3) according to the light thrown upon it by fig. 7. On the back of the antler the third tine, *d*, of fig. 3 is given off in an upward and backward direction. The beam, looked at from behind, presents a somewhat sigmoidal contour, as is generally the case with cervine antlers.

§ 3. *Measurements*.—In the following table the variations in the size of the antlers are shown. They are not compared with those of fallow deer, because in the latter the antlers have been modified to such a degree by domestication that the measurements of Museum specimens are of very little value. It is sufficient to say, in general terms, that the antlers of *Cervus Brownei* correspond in size with the average of those of the fallow deer in the English collections.

The maximum circumference of the beam is 5·8, the minimum 3·0 inches.

*Measurement of Antlers of Cervus Brownei.*

	British Museum.										
	37778 A	37778 B	37778 C	37778 D	27876	27883	37778 E	27976	37778 F	37778 G	37778 H
Circumference above the bur ( <i>a</i> ) .....	3·8	4·0	5·0	5·2	5·4	5·4	5·5	...	...	6·2	6·8
Maximum length of brow-tine ( <i>b</i> ) .....	...	...	...	...	5·4	4·8	6·5	...	...	...	...
Length of beam between brow- and second tine ( <i>c</i> ) .....	...	5·8	...	...	6·5	7·0	7·8	...	...	6·7	...
Breadth of second tine .....	...	...	...	...	1·5	1·05	1·35	...	...	...	...
Length of second tine .....	...	...	...	...	5·4	5·0	...	...	...	...	...
Length of beam between second and fourth tine ( <i>e</i> ) .....	...	...	...	...	3·6	...	...	...	...	...	...
Breadth of fourth tine ( <i>e</i> ) .....	...	...	...	...	1·75	...	...	...	...	...	...
Breadth of third tine ( <i>d</i> ) .....	...	...	...	...	0·75	...	...	...	...	...	...
Length of beam from base to third tine .....	...	...	...	...	18·0	...	...	...	...	...	...
Inner length of pedicle .....	...	...	...	0·92	...	0·62	1·1	0·8	0·8	0·7	...
Circumference of pedicle .....	...	...	...	4·1	...	4·8	5·0	5·0	5·3	5·6	...

§ 4. *Comparison with Cervus dama*.—The antlers of *Cervus Brownei* are totally unlike those of any existing species excepting *Cervus dama*, to which they approach so closely that the type specimen (fig. 3) was considered by Dr. Falconer<sup>1</sup> to belong to the latter. The basal half, indeed, so strongly resembles the corresponding portion of that

<sup>1</sup> Op. cit., vol. ii, p. 480.

of *Cervus dama* that it would be almost impossible to differentiate fragments from which the coronal portion had been broken away. But the resemblance ends at the second tine, *c*. If the series of antlers of *Cervus Brownei* (Pl. IV, figs. 1—7) be compared with those of the fallow deer which have been reproduced from Professor Blasius's<sup>1</sup> valuable work, there are these important differences. In the former the fourth tine (fig. 4, *e*) is developed on the anterior aspect, and the palmation of the antler is distinctly on the anterior aspect. In the latter (Pl. IV, fig. 8) the palmation is on the posterior aspect of the antler, which in the old bucks occupies a large portion of the posterior surface of the distal part of the antler. The fourth tine, *e*, is also normally absent from the latter, although, as is remarked by Sir Victor Brooke, it is present in some few exceptional cases. The three figured by that gentleman<sup>2</sup> are two wild, respectively from Greece and Sardinia, and one from a herd in a park. All three, however, have the normal posterior palmation, such, for example, as Pl. IV, fig. 9. These three or four exceptions to the general rule in the vast numbers in public and private collections, may be viewed as interesting cases of reversion to the type of *Cervus Brownei*—to an ancestral type—and as exact parallels to the occasional appearance of a three-toed horse in the domestic breeds.

§ 5. *The Relation of Cervus Brownei to C. Savini and C. dama.*—In the preceding chapter it was pointed out that *Cervus Savini* was closely allied to *C. Brownei*, and that the former is as yet only found in the early Pleistocene Forest-bed series of Norfolk and Suffolk. The latter is only known in the freshwater deposit of the Clacton shore, where it formed part of a Fauna of Mid-Pleistocene age.<sup>3</sup> Here it was associated with the following animals:

*Felis spelæa.*

*Bison or Urus.*

*Cervus elaphus.*

*Cervus megaceros.*

*Equus caballus.*

*Rhinoceros leptorhinus* of Owen.

(*Rhinoceros hemitæchus* of Falconer.)

*Elephas antiquus.*

This group of animals in the absence of Pleistocene species, and more particularly of the peculiar types of deer described in this Monograph from the Forest Bed, belongs to a later period than the Forest bed. It is therefore clear that the *Cervus Brownei* is later in point of time than the closely related form, *Cervus Savini*, described in the preceding chapter. The evidence is equally clear that it was succeeded in time by the existing species or variety, *Cervus dama*, which is of Pleistocene age on the Continent, but unknown in Britain until it was introduced by the Romans.<sup>4</sup> The three forms therefore stand to each other in the following relation in time:

<sup>1</sup> 'Fauna der Säugethiere Deutschlands,' vol. i, fig. 237. Braunschweig, 1857.

<sup>2</sup> 'Nature,' xi, p. 210, Jan. 14.

<sup>3</sup> Dawkins, 'Quart Journ. Geol. Soc.,' Lond., Aug., 1880, p. 397; "Early Man in Britain," p. 134.

<sup>4</sup> On this point, see the correspondence in 'Nature,' vol. xi, between Dr. Sclater (December 10th, 1874), myself (p. 71), and Sir Victor Brooke (p. 210).

Early Pleistocene (Pre-Glacial Forest Bed)	. . . . .	<i>Cervus Savini.</i>
Mid-Pleistocene (deposit at Clacton)	. . . . .	<i>C. Browni.</i>
Late Pleistocene (river deposits and cave deposits of Southern Europe)	. . . . .	<i>C. dama.</i>
Pre-historic (peat-bogs, alluvia, refuse heaps, cave deposits of Southern Europe)	. . . . .	„
Historic (Roman refuse heaps of Britain)	. . . . .	„

## CHAPTER V.

Pls. V, VI, VII.

*Cervus verticornis*, Dawkins.

§ 1. <i>Introduction.</i>	§ 3. <i>Measurements of Antlers.</i>
§ 2. <i>Definition of Antlers.</i>	§ 4. <i>The Skull.</i>
§ 5. <i>Range in Space and Time.</i>	

§ 1. *Introduction.*—A group of antlers from the Forest Bed of Norfolk in the Collections of the Rev. S. W. King and Mr. Jarvis, and of Mr. John Gunn, led me, in 1872,<sup>1</sup> to define the *Cervus verticornis* from all other Deer recent and fossil. In the present chapter I propose to bring together all the information which I have been able to obtain from the study of specimens discovered since that time.

§ 2. *The Definition of the Antlers.*—The large series of specimens, consisting of upwards of ninety in number, which I have studied in the various collections, allows me to show the stages in antler-development from youth to old age, and to mark the variations from the normal type. The characters of the antlers are as follows:—The pedicle is very short, not being more than two inches in length in any specimen which has passed through my hands. The base of the antler is cylindrical and strongly grooved, the grooves traversing the whole of the antler in its unworn condition, with the exception of the palmated areas and the tips of the tines. The bur, *a* (Pls. V, figs. 1, 3; Pl. VI, figs. 1, 2), is stout and set on at oblique angles to the main axis of the base of the beam. It is very generally worn away in the specimens which have been exposed to the action of the waves. The beam above the bur is cylindrical in the young antler (Pl. V, fig. 1; Pl. VI, fig. 2), but in the older ones is traversed by irregular elevations and depressions which destroy its cylindrical outline. The first tine, *b* (Pls. V, VI, VII), is stout, round in section, and springs from the beam generally at a distance of about two inches from the bur, and at an angle to axis of base of antler slightly greater than a right angle. In the young antler (Pl. V, fig. 1) it makes an angle of 126° with the main axis of the beam, and in figs. 2 and 3 of Pl. V, an angle of 135°. It first sweeps forwards and then downwards describing an arc, as may be seen in the figured skulls (Pl. VII, figs. 1 and 2).

It is this singular character that led me to give the distinctive name of *C. verticornis* to the species.

In the fine skull recently obtained by Mr. Backhouse from Kessingland (Pl. VII,

<sup>1</sup> 'Quart. Journ. Geol. Soc. Lond,' vol. xxviii, p. 407.



fig. 2), the first tine is perfect on both sides; it becomes straight after the basal curvature, and ultimately terminates in a tip slightly twisted forwards and upwards. It is nearly straight in the abnormal antler (Pl. VI, fig. 1).

In two other abnormal specimens of young antlers, in Messrs. Backhouse's and Savin's Collections, the basal portion of the first tine is straight and slightly waved. In six specimens an accessory tine is given off close to the bur, as, for example, in 33471 in the British Museum; and in a seventh and much younger antler in the Museum of the Geological Survey the same variation is to be seen. In several other cases (Pl. VII, fig. 1) "offers" *b'* are to be observed in the same position. We may, therefore, infer that the antlers of *Cervus verticornis* varied in this respect in the same way as those of the common stag, *Cervus elaphus*. Among abnormal forms, two antlers in Mr. Savin's Collection deserve notice, the first tine, *b*, being represented by an offer close to the bur in the one, and in the other by an offer 3.5 inches from the bur. In the first of these, which measures 5.6 inches in basal circumference, the bur is abnormally oblique and irregular. This character is repeated in a third antler in Mr. Backhouse's Collection, which is remarkable also for its small size and the relatively large development of the second tine. (See Table I, first column.)

The beam is slightly flattened (Pl. V, figs. 1, 2, 3; and Pl. VI) on its upper, and hollowed (Pl. V, fig. 1, A) on its lower surface at the point of junction with the first tine, *b*. Above this it recovers its cylindrical shape, but again becomes flattened anteriorly in a plane at right angles (Pl. V, fig. 1, A) to the above-mentioned flat surface. In some young, and very generally in the older antlers, a strong ridge defines these two flat surfaces, passing from the base of the first to the base of the second tine, *c*. In some cases it descends as far down as the bur. This region of the beam is rounder and smoother in the young than in the old animals.

The second tine, *c* (Pl. VI, fig. 2; Pl. VII, fig. 2), is oval at the base; and, springing from the anterior part of the beam from a plane below and at right angles to that of the first tine, *b*, terminates in a round point. It is nearly straight, with a slight wave, and forms a right angle, or nearly so, with the beam. In fig. 2 of Pl. VI, it forms an angle of 135°. Its position on the beam is variable, being two inches from the first tine, *b*, in fig. 2 of Pl. V, and seven inches in a specimen in Mr. Colman's Collection. The beam in some of the young and in all the old antlers is flattened in front at the point of junction with the second tine, then recovers its cylindrical shape, only to become flattened again as it arrives at the third tine, *d* (Pl. V, figs. 2, 3; Pl. VI, figs. 2, 3), which is given off from its posterior edge at a distance varying from twelve to thirteen inches from the bur. The third tine is directed backwards, almost at right angles to the beam, and from its oval section at the line of fracture in Pl. V, fig. 2, most probably terminated in a flattened point. Above the third tine, *d* (Pl. V, figs. 2, 3), the beam sweeps boldly forwards and upwards, forming in fig. 2 an angle of 107°, and in fig. 3 of 110° to the main axis, and becomes more and more flattened as it approaches the

fractured surface of the palmated crown, which in fig. 2 measures seven inches across. In a small specimen in Mr. Backhouse's Collection (Pl. VI, fig. 1), which is remarkable for the roundness of the beam and the obliquity of the bur, the antler is terminated by a broad, flattened crown, composed most probably of tines *d* and *f*. In fig. 2, of Pl. V, a constriction in the lower half implied that another tine, *f*, was given off before it terminated in the upper palmated tine or tines (fig. 2, *g*). This region is unfortunately wanting in all the specimens, probably because it is more easily destroyed than the stouter portions of the antler.

The large and old antler figured (Pl. V, fig. 3), throws off an additional tine, *e*, from its anterior surface in the space between the second, *c*, in front, and the third, *d*, behind. It is, therefore, clear that additional tines were developed in this region of the antler in the *Cervus verticornis* as in the case of *C. Savini* and in the living *C. dama*. This additional tine is oval in section at the base, and, like the second, *c*, set on at right angles to the beam.

The general sweep of the antlers of *Cervus verticornis* is sigmoid, the basal region rising to the first tine, *b*, the median being depressed to the second tine and in the older individuals to the third tine, *d*, and the upper rising abruptly from tine *d* to the palmated extremity. The general appearance of the antlers in the old adult may be gathered from the dotted outline added to Pl. V, figs. 2 and 3, the tines being added from other specimens, and the palmated crown from the original of fig. 2. It must, however, be remarked that the palmation of the crown may have been greater and the palm wider than in the outline. It is much less palmated than the antler of the Irish elk (*Cervus megaceros*), in which the flattening begins at the point where the second tine is given off, and in which the brow-tine sweeps straight forward to its bifurcated extremity, and is nearly in the same plane as the second tine. I am unable to recognise any affinity between these two types of antlers.

§ 3. *Measurements of antlers.*—The varying size of the antlers and the variation in the position of the tines in verticorn deer of different ages are shown in the following table of measurements :

TABLE I.

*Table of Measurements of Antlers of Cervus verticornis, Pleistocene Forest-bed Series.*

	Kessingland, Pakefield, Backhouse Coll.	Kessingland, Pakefield, Backhouse Coll.	Kessingland, Pakefield, Backhouse Coll.	Corton, Pl. V, fig. 1, Colman Coll.	Museum of Geological Survey.
Circumference of base of beam .....	4.25	5.0	5.0	5.5	5.8
Pedicle, length of .....	...	...	...	...	...
Pedicle, circumference of .....	...	...	...	...	...
Bur to tine 1, <i>b</i> .....	2.0	3.0	2.2	1.8	2.8
Bur to fork of tine 1 .....	3.1	3.8	3.8	3.0	4.0
Circumference of beam above tine 1 .....	4.4	...	5.5	5.0	5.8
Tine 1, basal circumference of .....	2.25	...	4.0	4.0	...
Tine 1, length of .....	4.0	...	...	3.0+	...
Tine 1 to tine 2, <i>c</i> .....	2.4	...	...	4.2	3.5
Tine 2, circumference of .....	3.1	...	...	...	...
Tine 2, length of .....	7.8	...	...	...	...
Circumference of beam above tine 2 .....	4.5	...	...	6.3	...
Bur to fork of tine 2 .....	6.5	...	...	9.0	...
Tine 2 to tine 3, <i>d</i> .....	...	...	...	...	...
Tine 2 to tine 4, <i>e</i> .....	...	...	...	...	...
Bur to tine 3 .....	...	...	...	...	...
Bur to fork of tine 3 .....	...	...	...	...	...
Tine 3, circumference of .....	...	...	...	...	...
Tine 3, length of .....	...	...	...	...	...
Circumference of beam above tine 3 .....	...	...	...	...	...
Bur to fork of tine 4 .....	...	...	...	...	...
Circumference of beam above tine 4 .....	...	...	...	...	...
Total length .....	...	5.0+	...	10.1+	9.0+

	Kessingland, Pakefield, Backhouse Coll.	Kessingland, Pakefield, Backhouse Coll.	Kessingland, Pakefield, Pl. VI, fig. 1, Backhouse Coll.	Kessingland, Pakefield, Pl. VI, fig. 2, Backhouse Coll.	British Museum.
Circumference of base of beam .....	5.8	5.8	6.1	7.0	7.2
Pedicle, length of .....	...	...	...	...	1.5
Pedicle, circumference of .....	...	...	...	...	7.0
Bur to tine 1, <i>b</i> .....	2.0	3.0	3.0	2.8	...
Bur to fork of tine 1 .....	3.5	4.0	4.5	3.9	...
Circumference of beam above tine 1 .....	5.0	...	6.1	7.1	...
Tine 1, basal circumference of .....	3.5	3.8	4.1	5.0	...
Tine 1, length of .....	...	...	6.5	6.2	...
Tine 1 to tine 2, <i>c</i> .....	...	...	5.4	5.8	...
Tine 2, circumference of .....	...	...	3.6	7.5	...
Tine 2, length of .....	...	...	5.1	7.8	...
Circumference of beam above tine 2 .....	...	...	11.5	11.0	...
Bur to fork of tine 2 .....	...	...	3.5	...	...
Tine 2 to tine 3, <i>d</i> .....	...	...	...	...	...
Tine 2 to tine 4, <i>e</i> .....	...	...	...	...	...
Bur to tine 3 .....	...	...	...	...	...
Bur to fork of tine 3 .....	...	...	13.5	...	...
Tine 3, circumference of .....	...	...	...	...	...
Tine 3, length of .....	...	...	...	...	...
Circumference of beam above tine 3 .....	...	...	...	...	...
Bur to fork of tine 4 .....	...	...	...	...	...
Circumference of beam above tine 4 .....	...	...	...	...	...
Total length .....	...	...	16.3+	17.0+	...

	Kessingland, Pakefield, Backhouse Coll.	British Museum.	Kessingland, Pl. V, fig. 2, Museum Geol. Survey.	Kessingland, Pakefield, Backhouse Coll.	Kessingland, Pakefield, Backhouse Coll.
Circumference of base of beam .....	7.2	7.4	7.5	7.8	8.0
Pedicle, length of .....	...	1.5	...	2.0	...
Pedicle, circumference of .....	...	8.3	...	8.0	...
Bur to tine 1, <i>b</i> .....	1.5	3.0	3.0	2.5	2.2
Bur to fork of tine 1 .....	3.5	...	5.0	4.0	3.8
Circumference of beam above tine 1 .....	...	...	7.5	6.9	7.1
Tine 1, basal circumference of .....	...	...	...	...	...
Tine 1, length of .....	...	...	...	...	...
Tine 1 to tine 2, <i>c</i> .....	...	...	2.0	5.0	...
Tine 2, circumference of .....	...	...	...	...	...
Tine 2, length of .....	...	...	7.8	...	...
Circumference of beam above tine 2 .....	...	...	...	...	...
Bur to fork of tine 2 .....	...	...	3.5	...	...
Tine 2 to tine 3, <i>d</i> .....	...	...	5.5	...	...
Tine 2 to tine 4, <i>e</i> .....	...	...	...	...	...
Bur to tine 3 .....	...	...	12.0	...	...
Bur to fork of tine 3 .....	...	...	13.5	...	...
Tine 3, circumference of .....	...	...	...	...	...
Tine 3, length of .....	...	...	6.0	...	...
Circumference of beam above tine 3 .....	...	...	9.0	...	...
Bur to fork of tine 4 .....	...	...	...	...	...
Circumference of beam above tine 4 .....	...	...	...	...	...
Total length .....	...	...	16.0+	...	...

	Corton, Colman Coll.	Corton, Colman Coll.	Kessing- land, Pakefield, Backhouse Coll.	Kessing- land, Pakefield, Backhouse Coll.	Kessing- land, Pakefield, Backhouse Coll.	Kessing- land, Pakefield, Skull, Pl. VII, fig. 2, Backhouse Coll.
Circumference of base of beam .....	8.2	8.2	8.4	8.5	8.5	8.6
Pedicle, length of .....	1.9	...	2.0	...	1.4	...
Pedicle, circumference of .....	7.9	...	9.0	...	8.5	...
Bur to tine 1, <i>b</i> .....	2.5	1.5	2.8	2.0	2.0	2.25
Bur to fork of tine 1 .....	4.5	3.0	4.2	4.0	4.0	4.5
Circumference of beam above tine 1 .....	7.8	7.2	7.6	8.1	7.4	7.9
Tine 1, basal circumference of .....	...	...	5.0	...	6.2	5.5
Tine 1, length of .....	...	...	3.0	...	...	10.3
Tine 1 to tine 2, <i>c</i> .....	...	7.0	5.5	3.5	...	5.5
Tine 2, circumference of .....	...	...	...	...	...	6.0
Tine 2, length of .....	...	7.8+	9.0+	8.0+	...	10.1
Circumference of beam above tine 2 .....	...	12.5	...	...	...	8.4
Bur to fork of tine 2 .....	...	...	...	...	...	...
Tine 2 to tine 3, <i>d</i> .....	...	...	...	...	...	...
Tine 2 to tine 4, <i>e</i> .....	...	...	...	...	...	...
Bur to tine 3 .....	...	...	...	...	...	...
Bur to fork of tine 3 .....	...	...	...	...	...	...
Tine 3, circumference of .....	...	...	...	...	...	...
Tine 3, length of .....	...	...	...	...	...	...
Circumference of beam above tine 3 .....	...	...	...	...	...	...
Bur to fork of tine 4 .....	...	...	...	...	...	...
Circumference of beam above tine 4 .....	...	...	...	...	...	...
Total length .....	...	17.0+	17.0+	14.5+	...	...

	Kessing- land, Pakefield, Skull, Pl. VII, fig. 1, Backhouse Coll.	British Museum.	Trimling- ham, Savin Coll.	Kessing- land, Backhouse Coll.	West Ranton, Savin Coll.	Kessing- land, Pakefield, Pl. V, fig. 3, Backhouse Coll.
Circumference of base of beam .....	8.6	8.5	8.8	10.0	10.2	10.4
Pedicle, length of .....	2.0	...	...	2.0	...	...
Pedicle, circumference of .....	9.1	...	...	8.9	9.4	...
Bur to tine 1, <i>b</i> .....	2.0	1.7	2.5	...	2.0	1.5
Bur to fork of tine 1 .....	4.0	3.7	4.0	...	4.0	4.0
Circumference of beam above tine 1 .....	8.0	...	7.9	...	...	10.1
Tine 1, basal circumference of .....	...	...	5.0	...	...	6.0
Tine 1, length of .....	...	...	...	9.5	...	7.0
Tine 1 to tine 2, <i>c</i> .....	...	5.0	6.0	...	3.0	4.8
Tine 2, circumference of .....	...	...	...	...	...	5.0
Tine 2, length of .....	...	...	...	...	...	...
Circumference of beam above tine 2 .....	...	...	...	...	8.1	10.7
Bur to fork of tine 2 .....	...	...	...	...	...	...
Tine 2 to tine 3, <i>d</i> .....	...	...	...	...	...	...
Tine 2 to tine 4, <i>e</i> .....	...	...	...	...	...	3.5
Bur to tine 3 .....	...	...	...	...	...	13.0
Bur to fork of tine 3 .....	...	...	...	...	...	15.0
Tine 3, circumference of .....	...	...	...	...	...	...
Tine 3, length of .....	...	...	...	...	...	...
Circumference of beam above tine 3 .....	...	...	...	...	...	10.8
Bur to fork of tine 4 .....	...	...	...	...	...	13.6
Circumference of beam above tine 4 .....	...	...	...	...	...	9.5
Total length .....	...	...	...	...	19.5+	21.0+

	Kessing- land, Pakefield, Backhouse Coll.	British Museum.	Pleiocene.	Cervus Megaceros, Ballybeta Bog, Dublin. Manchester Museum.		
			Trimley, Red Crag, Pl. VI, fig. 3, Brit. Mus.			
Circumference of base of beam .....	10.5	11.0	8.2	11.8	12.0	15.0
Pedicle, length of .....	...	...	...	...	...	...
Pedicle, circumference of .....	...	...	...	10.0	12.3	...
Bur to tine 1, <i>b</i> .....	2.5	1.0	1.7	...	...	...
Bur to fork of tine 1 .....	5.0	4.0	3.7	2.0	2.2	2.0
Circumference of beam above tine 1 .....	9.0	...	7.0	8.5	8.8	11.2
Tine 1, basal circumference of .....	6.9	7.5	...	...	...	...
Tine 1, length of .....	...	...	...	...	...	...
Tine 1 to tine 2, <i>c</i> .....	...	...	4.0	8.5	9.5	...
Tine 2, circumference of .....	...	...	...	...	...	...
Tine 2, length of .....	...	...	...	...	...	...
Circumference of beam above tine 2 .....	...	...	7.1	...	...	...
Bur to fork of tine 2 .....	...	...	...	...	...	...
Tine 2 to tine 3, <i>d</i> .....	...	...	...	...	...	...
Tine 2 to tine 4, <i>e</i> .....	...	...	...	...	...	...
Bur to tine 3 .....	...	...	13.0	12.0	...	...
Bur to fork of tine 3 .....	...	...	...	...	...	...
Tine 3, circumference of .....	...	...	...	...	...	...
Tine 3, length of .....	...	...	...	...	...	...
Circumference of beam above tine 3 .....	...	...	...	...	...	...
Bur to fork of tine 4 .....	...	...	...	...	...	...
Circumference of beam above tine 4 .....	...	...	...	...	...	...
Total length .....	...	...	17.6+	...	...	...

§ 4. *The Skull*.—The fragments of skulls which have passed through my hands, proved by the antlers which are attached to them to belong to this singular cervine form, consist of twelve frontlets and various portions of the occipital and frontal regions. The singular forward and downward sweep of the brow-tine over and at the outside of the orbits is very well seen in the figured specimens belonging to Mr. Backhouse (Pl. VII, figs. 1 and 2). The pedicles are set on the frontals at an angle varying from  $30^{\circ}$  to  $40^{\circ}$ , taking the frontal plane between them as a base, and the antler is less erect and extends further away from the median line than in most of the deer. This character is very well shown in a specimen belonging to Mr. Savin from West Runton. The frontals between the pedicles are slightly depressed, and do not bear a bold ridge on the inter-frontal suture, as in *Cervus megaceros*. They are depressed and slightly hollowed in front of the pedicle, and the surorbital groove is not so strongly marked as in the above-mentioned animal.

The measurements in the following table show that there was little difference in point of size between *Cervus verticornis* and the great Irish deer, *Cervus megaceros*.

TABLE II.  
*Measurements of Skulls of C. verticornis.*

	Pl.VI,fig.2, Backhouse Coll., Pakefield, Lowestoft.	Pl.VI,fig.1, Backhouse Coll., Pakefield, Lowestoft.	Backhouse Coll., Pakefield, Lowestoft.	49,429, British Museum.	49,430, British Museum.	West Runton, Savin Coll.	<i>Cervus megaceros</i> , Ballybeta Bog, Dublin.	
Occipital crest to fronto- parietal suture.....	3·0	4·2	...	4·2	...	...	...	...
Occipital crest to pedicle	3·25	3·2	2·5	...	...	...	3·0	3·5
Width of frontals be- tween pedicles.....	2·5	2·5	...	...	...	2·5	...	...
Width of frontals be- tween surorbital fora- mina .....	4·5	4·0	...	4·0	4·0	5·0	5·0	4·5
From bur to bur.....	4·6	4·0	...	4·8	4·7	4·0	4·0	4·0
Top of foramen magnum to occipital crest.....	...	...	4·0	3·0	...	...	4·0	4·9
Foramen magnum:								
Height .....	...	1·8	1·4	1·6	...	...	1·8	1·6
Width .....	...	1·5	1·0	1·25	...	...	1·5	1·2
Basi-occipital to end of basi-sphenoid .....	...	...	...	4·0	...	...	...	...

§ 5. *The Range of Cervus verticornis in Space and Time*.—It remains now to inquire into the range in space and in time of this singular extinct deer. Its remains occur in considerable numbers in the Forest-bed series at Kessingland and Pakefield in Suffolk, and range through the various subdivisions of the same beds at Mundesley, Trimmingham, Overstrand, Sidestrand, Cromer, and West Runton in the district of Cromer in Norfolk.

The strata in which they are found clearly underlie the Glacial deposits in the cliffs, and belong to the early division of the Pleistocene formation. The *Cervus verticornis* therefore inhabited the valley of the North Sea before the submergence of the British area beneath the berg-laden Glacial sea. It is not found either in the Mid-Pleistocene or in the Late Pleistocene strata, and probably became extinct during the geographical and climatical changes which took place at the close of the Early Pleistocene age. Hitherto I have sought for it in vain in the museums of France and Italy, and its range in space, so far as it is known, is restricted to Norfolk and Suffolk. Its range in time is, however, extended backwards into the Pleiocene by an antler in the British Museum (Pl. VI, fig. 3), obtained by Mr. Charlesworth from the Red Crag of Trimley near Felixstowe, and identified by me as belonging to this species in 1874. The associated Mammalia in the same deposit are *Mastodon arvernensis*, and an elephant identified by Dr. Leith Adams with *Elephas antiquus*.<sup>1</sup> It is therefore a Pleiocene deer which survived into the early Pleistocene age.

<sup>1</sup> Collected by Dr. Reed, and preserved in the museum at York. See 'Monograph on Fossil Elephants,' pl. xxvi, figs. 2 and 4 (Palæontographical Society).







PLATE I.

*References to figures.*

*a.* Bur. *b.* First tine. *c.* Second tine. *d.* Third tine. *e.* Fourth tine. *f, g, h, i.* Terminal tines of crown. *pe.* Pedicle. *fr.* Frontal. *pa.* Parietal.

*Alces latifrons*, Dawkins.

Chapter I, pp. 1—6.

FIG.

1. A skull with left antler attached. Savin Collection. Weybourn beds (Forest-bed series), East Runton, Cromer. One fourth natural size.
2. A frontlet. Gunn Collection, Norwich Museum. Forest Bed, Kessingland, Norfolk. One fourth natural size.
3. Left antler attached to frontal. Savin Collection. Weybourn beds (Forest-bed series), Cromer. One half natural size.
4. Right antler attached to frontal. Savin Collection. Forest Bed, Overstrand, Cromer. One fourth natural size.
5. Right antler attached to frontal. Savin Collection. Forest Bed, Sidestrand, Cromer. One fourth natural size.
6. Left antler attached to frontal. Johnson Collection. Forest Bed, Happisburg (Hasborough), Cromer. As the original was inaccessible, the figure is lithographed from a drawing. One fourth natural size.
7. Skull with antlers of *Alces machlis*. No. 1627, Museum of Royal College of Surgeons, London. One eighth natural size.







## PLATE II.

*Cervus Dawkinsi*, Newton.

Chapter II, pp. 7—10.

For lettering of figures see explanation of Plate I.

FIG.

1. Superior surface of shed left antler. In the Museum of the Geological Survey, Jermyn Street, London. From the Forest Bed of Norfolk. One fourth natural size.
2. Superior surface of shed left antler, older than the above. In the Norwich Museum. From the Forest Bed at Bacton. One fourth natural size.
- 2 A. Profile of base showing "offer" *b*'. One fourth natural size.

CERVUS DAWKINSI, Newton.









### PLATE III.

*Cervus Dawkinsi*, Newton.

Chapter II, pp. 7—10.

For lettering of figures see explanation of Plate 1.

FIG.

1. Left antler. Superior surface. Savin Collection. Forest Bed, Sidestrand, Cromer.  
One fourth natural size.
- 1 A. Ditto. Anterior surface.

*Cervus Savini*, Dawkins.

Chapter III, pp. 11—16.

2. Young antler, shed right side; superior surface. Savin Collection. Weybourn beds, East Runton, Cromer. One fourth natural size.
3. Adult antler, shed left side. Savin Collection. Forest-bed series, Trimmingham, Cromer. One fourth natural size.
4. Old antler, right side; superior surface. Savin Collection. Forest-bed series, Sidestrand, Cromer. One fourth natural size.
5. Frontlet with antlers. Backhouse Collection. Forest-bed series, Kessingland, Pakefield, Lowestoft. One fourth natural size.



FIGS. 1. 1A. CERVUS DAWKINSI, NEWTON. FIGS. 2, 3, 4, 5. C. SAVINI, DAWKINS.





PLATE IV.

*Cervus Browni*, Dawkins.

Chapter IV, pp. 17—21.

For lettering of figures see explanation of Pl. I.

FIG.

- 1—7. A series of antlers in the British Museum, from the Mid-Pleistocene deposit at Clacton, Essex. One fourth natural size.
8. A series of antlers of the *Cervus dama*, Linnæus. After Blasius, illustrating the normal changes of form.
9. Abnormal antler of *Cervus dama*. After Sir Victor Brooke, Bart., 'Nature,' vol. xi, p. 210, fig. 4.









PLATE V.

*Cervus verticornis*, Dawkins.

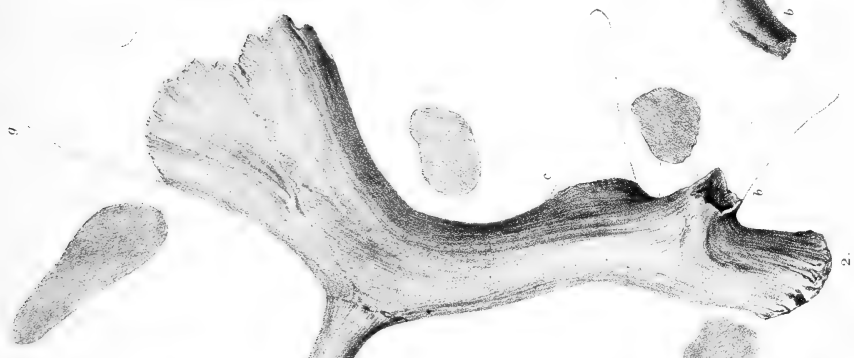
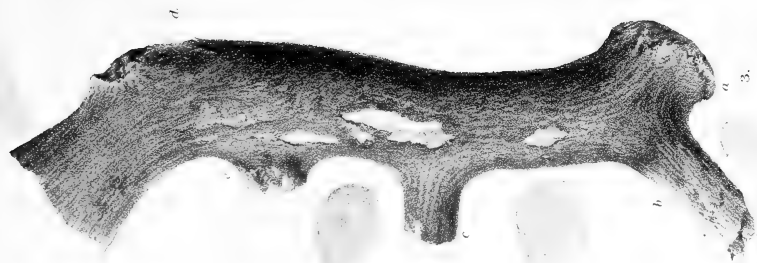
Chapter V, pp. 22—29.

For lettering of figures see explanation of Plate I.

FIG.

1. Young antler, shed, left side ; superior surface. Colman's Collection. Forest-bed series, Corton, Lowestoft. One fourth natural size.
  - 1 A. Infero-outer surface of ditto.
2. Older antler, shed, left side ; superior surface. In the Museum of the Geological Survey, Jermyn Street. Forest-bed series, Kessingland, Pakefield, Lowestoft, Suffolk. One fourth natural size.
3. Old antler, shed, right side ; superior surface. Backhouse Collection. Forest-bed series, Kessingland, Pakefield, Lowestoft, Suffolk. One fourth natural size.

g







## PLATE VI.

*Cervus verticornis*, Dawkins.

Chapter V, pp. 22—29.

For lettering of figures see explanation of Pl. I.

FIG.

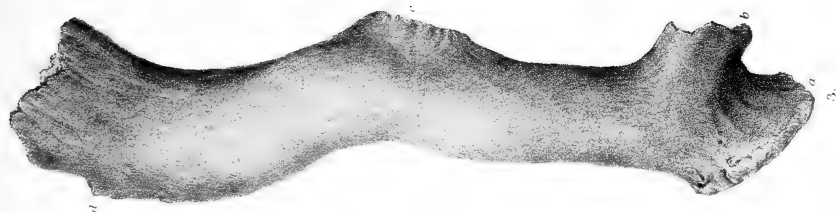
1. Shed antler, left side ; superior surface. Backhouse Collection. From the Forest-bed series, Pakefield, Lowestoft. One fourth natural size.
2. Shed antler, left side ; superior surface. Backhouse Collection. From the Forest-bed series, Pakefield, Lowestoft. One fourth natural size.
3. Shed antler, left side ; superior surface. No. 45,929 in British Museum. From the Red Crag [Pleiocene] of Trimley, Felixstowe, Suffolk. One fourth natural size.



W. J. M. Rose del. et lith.



CERVUS VERTICORNIS, I. avilinae.



Wm. Newman & Co. imp.





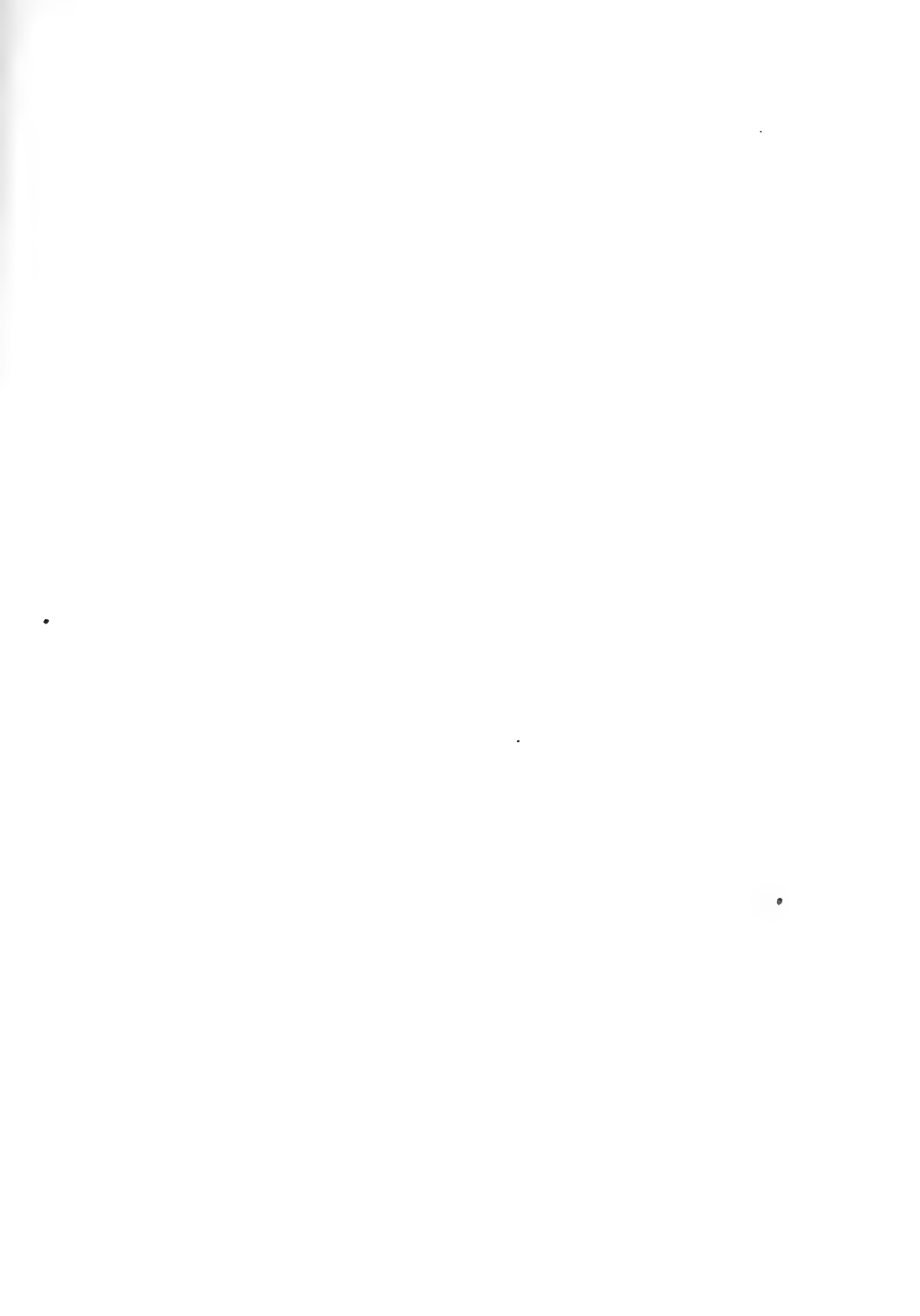


PLATE VII.

*Cervus verticornis*, Dawkins.

Chapter V, pp. 22—29.

For lettering of figures see explanation of Pl. I.

FIG.

1. Skull with antlers; superior surface. Backhouse Collection. Forest-bed series,  
Kessingland, Pakefield, Lowestoft. One fourth natural size.
2. Ditto Ditto.

















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